Winslow Homer: *The Adirondack Guide*, **1894**

An Updated Diagnostic and Feasibility Study for Lake Sallie, Detroit Lakes, MN

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Summary

Project Background
Lake Sallie has been the subject of ongoing water quality monitoring conducted since the 1940s with the objectives of finding the sources contributing to the water quality degradation in Lake Sallie. Water quality improvement projects have been implemented over the years, but Lake Sallie still experiences occasional summer nuisance algae blooms.

Reasons for the Study
The purpose of this report was to evaluate new data collected since the last major report was completed in 1993, to evaluate water quality trends, and to prepare a revised implementation plan for Lake Sallie. The objectives were to find project that lessen nuisance algae blooms in Lake Sallie.

Lake Water Quality Goal
The water quality goal for Lake Sallie is to improve conditions to be comparable to other nearby lakes. This would require a Carlson Trophic State Index of less than 50. Reference lakes in the vicinity average 45 on the index.

Watershed Characteristics
Direct drainage area: 2,670 acres
Contributing surface watershed: 58,378 acres
Average annual inflow to Lake Sallie: 22,000 ac-ft
Important Lakes in the Watershed: Muskrat Lake, Detroit Lake, Lake St. Clair, Floyd Lake, Little Floyd Lake

Lake Characteristics
Lake area: 1,211 acres
Maximum depth: 55 feet; **Average depth:** 17 feet
Water clarity: 1996 summer average: 8.0 feet (range 3.0 - 20.9 feet)
Dissolved oxygen and Temperature: In 1996 the lake was mostly well-mixed, with occasional weak stratification; dissolved oxygen present throughout the lake in summer.
Phosphorus: 1996 summer average: 38 ug/l (range 15 - 65 ug/l)
Aquatic plants: Northern milfoil and coontail are abundant.
Fish: The population density of bullheads has fluctuated over the last fifty years. Panfish populations are on the rise. The walleye population has remained relatively constant with a natural reproducing population present..

Important Findings of This Study

- A harsh winter (early snow, long ice season) contributes to producing anoxic conditions in Lake St. Clair and Muskrat Lake. With a loss of oxygen in these shallow lakes, significant phosphorus release from lake sediments occurs. With ice out and spring runoff, spring nutrient loads out of these systems are higher compared to years with milder winters.
- In mid to late summer, nutrient loading from groundwater discharge to Ditch 14 is an important nutrient source to Muskrat Lake. If Muskrat Lake cannot assimilate this phosphorus load, then it will pass through into Lake Sallie.
- When internal loading from Lake Sallie occurs, nuisance algae blooms seem to occur.
- If internal loading in Lake Sallie can be reduced, acceptable lake water quality is predicted.
- Although water quality trends indicate Lake Sallie is improving (based on phosphorus, algae, and fish indicators), it is still eutrophic.

Lake Sallie Improvement Strategies

Sources of Phosphorus: The impacts from past sewage treatment effluent discharges in the watershed may still be impacting Lake Sallie. Lake St. Clair sediments and Ditch 14 wetlands may have accumulated phosphorus by receiving treatment plant discharges and phosphorus continues to leach out even though wastewater treatment discharges are greatly reduced. It appears that Lake St. Clair releases excessive phosphorus in early spring. We suspect elevated phosphorus may be from internal loading occurring during ice-covered winter months.

In summer, surface water in Ditch 14 appears to have elevated phosphorus concentrations. A Watershed District study in the summer of 1996 found elevated phosphorus concentrations in the wetland soil interstitial water (pore water) of 500 to over 1,000 parts per billion of phosphorus. We have not determined if the source of high pore water phosphorus is from groundwater with elevated phosphorus concentrations or if pore water is receiving phosphorus from wetland soils leaching phosphorus. Wetland soils may have been loaded with phosphorus from previous wastewater treatment plant discharges. Since 1976, there has been a dramatic decrease in phosphorus in the wastewater discharged in the Lake Sallie watershed, however there may still be a considerable amount of phosphorus in the wetland soils. More work will be needed to address this.

Recently, in years when internal phosphorus loading has occurred in Lake Sallie, nuisance algae blooms have occurred. In years when internal loading does not occur, Lake Sallie, for the most part, has low level algae blooms and acceptable water transparency for a large part of the summer. If we could reduce internal loading in Lake Sallie, we may be able to achieve water quality goals, throughout most of the summer.

Our question is how to reduce internal loading in Lake Sallie. A lake wide alum treatment would probably solve this, however, there is a risk of adverse impacts to the high quality fish community, the alum treatment is costly, and there is no guarantee it would work or if it did work, we don't know how long it would be effective.

Strategy: Our strategy is to reduce internal loading in Lake Sallie by reducing watershed phosphorus loading. It is likely that spring phosphorus loading into Lake Sallie can produce a significant diatom population which settles out of the water column in May. When this biomass decomposes it can stimulate two processes: first phosphorus is released directly into the water column as part of algae cell decomposition, and secondly, there is an oxygen demand created as decomposition progresses. In years with high spring phosphorus inputs to Sallie, there may be more diatom production, and a subsequent high oxygen demand. This in turn could create anoxic conditions in the bottom water which could promote significant phosphorus release from Lake Sallie sediments.

If we can reduce spring phosphorus loading to Lake Sallie, we may reduce biomass (algae) production. To reduce spring phosphorus loading, one approach is to reduce the spring loading from Lake St. Clair at its source, which is suspected to be the lake sediments, by using a whole-lake alum sediment treatment. This would reduce spring phosphorus inputs into Lake Sallie.

We have a different strategy for reducing summer phosphorus loading to Lake Sallie from Ditch 14. It would be difficult (but not impossible) to reduce the phosphorus loading at the source which is probably the Ditch 14 wetland soils. For reducing midsummer phosphorus loads from Ditch 14 we propose to enhance biomanipulation effects in Muskrat Lake as a way of dampening the phosphorus load from Ditch 14 sources.

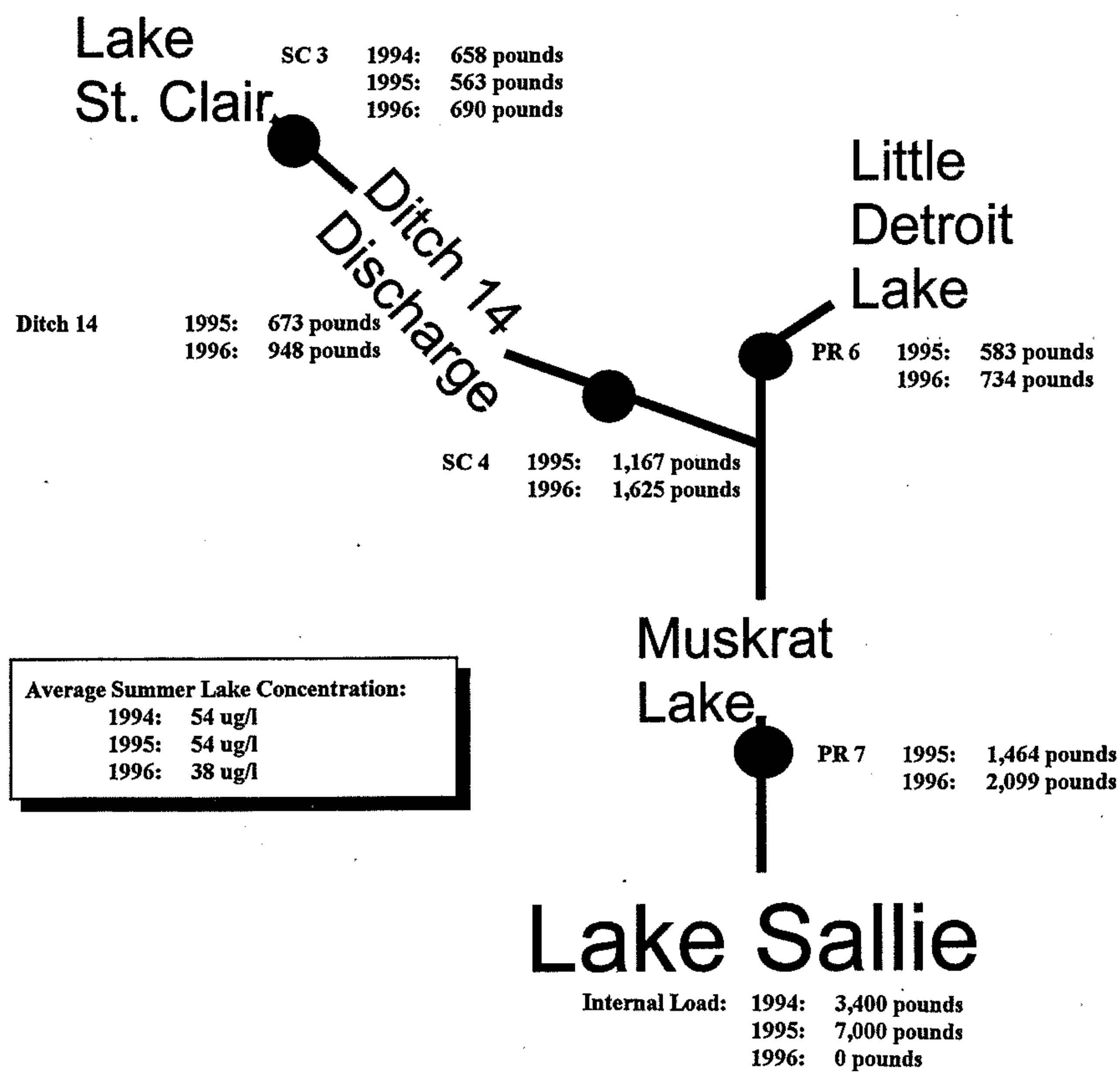
Summary: We are proposing an ecosystem management approach that stresses sound watershed clean water practices combined with work in other watershed water bodies to improve water quality conditions in Lake Sallie. These approaches are lower in cost and environmental impacts compared to a Lake Sallie alum treatment which would be over $400,000.

If our ecosystem projects were found to not produce improved water quality in Lake Sallie, we could then implement what we are calling, "reserve projects" to reduce phosphorus concentrations and nuisance algae conditions in Lake Sallie.

The implementation plan is set up to be a phased lake improvement program. With low cost projects being implemented first, and if they don't work, a sequence of several other projects could be considered.

Phosphorus Loading to Lake Sallie

(March through September)



A summary of phosphorus loading sources and quantities to Lake Sallie for 1994, 1995, and 1996. Loads vary from year to year. It appears that the spring phosphorus loads to Lake Sallies influence anoxic conditions in Lake Sallie and the magnitude of internal phosphorus release.

Summary of Proposed Watershed and Lake projects for Lake Sallie

Projects	How They Benefit Water Quality
1. WATERSHED PRACTICES TO REDUCE PHOSPHORUS INPUTS TO LAKE SALLIE.	By protecting Detroit Lake, we maintain a low phosphorus concentration in the outflow and a low loading rate from Detroit Lake into Sallie. Currently, loading from Detroit Lake is acceptable. We also want to maintain ongoing BMP implementation in the direct drainage watershed of Lake Sallie.
2. SPECIAL WATERSHED PROJECTS **a. Alum treatment in Lake St. Clair**	Lake St. Clair outlet sampling results indicate high phosphorus loads in spring and lower loads in summer. We suspect that shallow Lake St. Clair loses water column oxygen over winter and experiences significant internal phosphorus loading. An alum treatment would reduce winter sediment phosphorus release and reduce spring phosphorus loading from Lake St. Clair.
b Improve boat access an Muskrat Lake and harvest filamentous algae and cut fish cruising lanes	We found that significant amount of phosphorus discharges from the wetland complex between Lake St. Clair and Muskrat Lake during the summer. We would like to reduce the phosphorus load before it gets to Lake Sallie. We have a two-fold strategy: 1) Use aquatic plants in Muskrat Lake to help remove phosphorus and 2) Use gamefish to control small fish, which produces a biomanipulation effect. To improve aquatic plants in Muskrat Lake, harvesting of filamentous algae would help. This allows more sunlight to get to the plants. To get a harvester into Muskrat, a better access would be needed. To allow gamefish good access to the small fish, cruising lanes could be cut into the weed beds in Muskrat Lake Custom harvesting would allow maximum fish effects while maintaining a good aquatic plant community.
c. Winter aerator, on standby, to prevent winterkill in Muskrat Lake, combined with fish stocking.	Over a long, cold winter, Muskrat Lake could be susceptible to winterkill, especially if the Pelican River freezes over. To maintain a robust predator fish population, a winter aeration unit should be available, if needed, to make sure there is not a catastrophic fish kill. Depending on angler fishing pressure and other factors, it may be necessary to supplementally stock Muskrat lake with gamefish. This is to maintain control over small fish. As long as an aerator is on reserve, it should be acceptable to "beef" up the gamefish through stocking.
d. Wetland projects: checking phosphorus sources and studying phosphorus reductions projects.	In 1996 we found strong evidence for significant phosphorus discharge from Ditch 14 wetland systems. Additional work is needed to find the source of the phosphorus. If phosphorus reduction from the wetland complex on Ditch 14 is necessary, an option may be groundwater aeration. A small-scale demonstration would help to determine the feasibility of a large-scale project.
3. ON-GOING LAKE SALLIE PROJECTS **a. Aquatic plant and filamentous algae harvesting**	Harvesting on Lake Sallie reduces nuisance conditions associated with rapidly growing plant communities. Although aquatic plants are desirable in lakes, harvesting facilitates plant management while sustaining aquatic plant community benefits.
b. Control of Flowering Rush	Aquatic plant harvesting should control the exotic flowering rush.
c. Continued lake sampling for trend analyses	We need to keep monitoring Lake Sallie to check the phosphorus status. Incoming phosphorus and internal release need to be characterized. If trends show that Lake Sallie is not improving based on the projects that have been implemented, then the reserve projects may be called for.
4. RESERVE PROJECTS **a In-lake alum treatment of Muskrat Lake**	Another way to remove phosphorus associated with Ditch 14 may be to do a one-time alum treatment in Muskrat Lake. Research has shown that a sediment alum treatment may remove water column phosphorus as well as inactivating sediment phosphorus. Therefore, as Ditch 14 water flows through Muskrat Lake on the way to Lake Sallie, phosphorus could be removed in Muskrat Lake.
b. Alum dosing on Ditch 14	Previous research has shown that alum injection into water or groundwater will reduce orthophosphorus concentrations. If summertime phosphorus from Ditch 14 is not being adequately handled in Muskrat Lake, and if aeration is not feasible, then alum dosing could be considered. At the present time, drinking water standards for aluminum apply and it would be fairly expensive to install an alum dosing system.
c. In-lake alum treatment of Lake Sallie	An option for improving Lake Sallie by way of reducing internal loading is a whole-lake sediment alum treatment. There are enough examples to indicate it would have a high probability of working. However, there is a possibility of adversely impacting the benthic invertebrate community which, ultimately, could effect the high quality walleye population. Also a whole-lake alum treatment would be expensive. This project is a reserve project and would be considered only after earlier options were installed and did not work.

Phase II Budget: A summary of the project budget is summarized below.

Program Element	Project Cost	State/ Federal (in-kind)	Local (in-kind)	Local (cash)	MPCA (cash)	MPCA (loan)
1. Implementation Projects						
1. Watershed BMPs **1.a.** Detroit Lake storm water runoff treatment installation	170,000	0	0	0	0	170,000
1.b. Septic system monitoring/upgrades/sewer conversions	8,000	0	0	8,000	0	0
1.c. Shoreland zone management practices	10,000	2,000	8,000	0	0	0
1.d. Improve feedlot and other agricultural practices	60,000	40,000		20,000	0	0
1.e. Streambank protection and stabilization	12,000	0	6,000	6,000	0	0
2. Special Watershed BMPs **2.a.** Lake St. Clair alum treatment	40,000	0	0	0	0	40,000
2.b. Improve boat landing and conduct harvesting on Muskrat Lake	22,000	0	0	0	6,000	16,000
2.c. Winter aerator for Muskrat Lake	33,000	0	0	0	0	33,000
2.d. Wetland projects	33,000	0	3,000	0	30,000	0
3. On-going Lake Sallie Projects **3.a.** Aquatic plant harvesting	60,000	0	60,000	0	0	0
3.b. Control of Flowering Rush	60,000	0	60000	0	0	0
3.c. Continued lake sampling for trend analysis	18,000	0	6,000	0	12,000	0
4. Reserve Projects **4a.** Muskrat Lake alum treatment	26,000	0	0	0	0	26,000
4b. Alum dosing on Ditch 14	100,000	0	0	0	0	100,000
4c. Lake Sallie alum treatment	400,000	0	0	0	0	400,000
5. Information Education	23,000	0	12,000	11,000	0	0
6. Monitoring **6a.** Routine lake and watershed	48,000	0	24,000	24,000	0	0
6b. Project evaluation	30,000	2,000	10,000	12,000	6,000	0
7. Project Management **7a.** Project meetings/administration	15,000	0	10,000	5,000	0	0
7b. Reports	22,000	2,000	14,000	6,000	0	0
7c. Printing & Mailing	8,000	0	0	8,000	0	0
TOTALS	1,198,000	46,000	213,000	100,000	54,000	785,000

Eligible Project Costs: $1,198,000
Eligible State Federal Cost Share and In-Kind: $46,000
Eligible Local In-Kind and Cash: $313,000
MPCA Grant Request: $54,000   MPCA Loan Request: $785,000

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1. Introduction

1.1. Scope and Purpose

Official recognition of poor water quality conditions in Lake Sallie began in the 1940's. Work to improve water quality conditions in Lake Sallie have been ongoing since the late 1940s (Moyle and Wilson 1948). A Phase I Clean Lakes Grant was awarded to the Pelican River Watershed District in September 1987. In June 1990, a draft report was submitted, and it was resubmitted in July 1992. A revised Phase I draft was submitted in December 1993.

In 1994, 1995, and 1996, a high intensity monitoring program was conducted in the Lake Sallie watershed. This current report summarizes work that has been done since the December 1993 report was submitted and reviews past data also.

The purpose of this report was to evaluate data collected through 1996, to evaluate water quality trends, and to prepare a revised implementation plan for Lake Sallie.

1.2. Water Quality Goals

With respect to water quality, the general goal of the Pelican River Watershed District is to retard the eutrophic processes for purposes of enhancing recreational and aesthetic attributes of all watershed lakes. This general goal subsumes improved water clarity, control of aquatic plants which interfere with swimming, boating and fishing, reduction in algal blooms, especially the blue-green variety which detract from the aesthetic experience, and improvement of gamefish populations.

Water Quality Goals for Lake Sallie

Lake Sallie seems to have water quality conditions that are substantially inferior to other comparable lakes in the area (Table 1).

Table 1. Trophic State Indices (transparency); Study Lakes and Reference Lakes. Source: MPCA, Reports on Transparency of Minnesota Lakes, 1988, 1990. Lake Sallie and Detroit values from Phase I study (1988).

	Summer Averages	Minimum Transparency
LAKE SALLIE	54	64
DETROIT LAKES	46	54
Reference Lakes in PRWD		
Floyd	48	54
Melissa (1990)	46	53
Long	38	51
Fox	46	51
AVERAGE	45	53
Other Nearby Reference Lakes		
Boot	38	44
Buffalo	48	53
Island	46	53
Middle Cormorant	43	46
Bad Medicene (1989)	39	43
White Earth (1987)	42	50
Eunice (1990)	43	42
Little Cormorant (1987)	55	59
Maud	42	46
Pelican	42	47
AVERAGE	44	48

While significant progress has been made in improving the quality of Lake Sallie's water since 1976, the lake still experiences nuisance conditions, including extensive weed growth and algae blooms which detract from the lake as a recreational and aesthetic resource. This evidence together with that offered by the Trophic State Indices, suggest that Sallie remains in the early stages of Eutrophy. Moreover, these are symptoms that in spite of recent improvements, suggest that the lake could deteriorate further; the legacy of inaction now could be severe, perhaps irreparable, damage.

Lake Sallie's water quality is subject to wide swings, apparently in response to relatively large releases of nutrients during summer periods of hypolimetic anoxia. These recurrent mid-summer episodes of extremely poor conditions, which fall statistically in the hypereutrophic range, play a large role in defining Sallie's overall water quality problem. Thus the aesthetic and recreational conditions desired by residents and other lake users are annually compromised by the mid-summer smell, look and feel of large algal blooms and rapid weed growth.

Lake Sallie's water quality goals are to bring the lake in line with other lakes in the region and to maintain the positive water quality trends that have been observed in the last fifteen years.

Having fully considered these issues, and given that there are still some things which we do not fully understand about the mechanisms which depress Lake Sallie's water quality, The Pelican River Watershed District hereby establishes the following goal for Lake Sallie: Lake Sallie's water quality should be improved to that of other nearby lakes.

As an operational guideline, programs will be aimed at lowering average Trophic State indices below the arbitrary mesotrophic-eutrophic boundary of 50, and elimitating mid-summer episodes of high loadings of phosphorus from internal sources.

This goal is purposely broad, and , given the current conditions of Lake Sallie, unquestionably ambitious. It is intended to apply to both average conditions and extreme events. Yet under the circumstances of the long-standing root causes of Sallies's problem, and the matter of equity of resource allocations by the Pelican River Watershed District, as well as those of Becker County and the State of Minnesota, the District believes that this goal is appropriate and reasonable.

To lower Sallie's extreme events to the average of other nearby lakes will require an increase in minimum transparency by about one meter and would require a reduction of extreme event Chlorophyll a or phosphorus level observations of about 50 percent.

Here it is noteworthy that a reducing in the severity of Lake Sallie's extreme events to the average of nearby lakes would alone improve the summer average trophic lakes. Another way of putting this is that Lake Sallie's current underlying nutrient situation is not greatly different from that of other lakes in the general area. Rather it is extremely high release of phosphorus from bottom sediments during episodes of mid-summer anoxia, that are most influential in defining Sallie's water quality.

The strategy for achieving the goal is complicated by the fact that the lake's internal loading problems cannot be solved without first reducing the in-flow of nutrients (especially phosphorus). This in turn is further complicated by the fact there is a strong suspicion that some nutrients entering Sallie are released from stored sediments in lakes and wetlands upstream from Lake Sallie.

Accordingly the following general steps are required to achieve the goal:

1. Adopt a full range of best management practices to ensure that water entering Sallie from all sources, is as free from sediments and nutrients as we can make it.

2. Control the releases from residual nutrient build-up in several key upstream locations, most notably in the St. Clair subwatershed.

3. Undertake measures that will reduce internal loading from residual nutrients stored in Lake Sallie's bottom sediments.

The order of these steps is purposeful, and reflects in a general way the order in which various corrective actions should be taken.

1.3. Summary of Previous Work in the Lake Sallie Watershed

The water quality of Lake Sallie has been the subject of many studies over the past 50 years. Studies by John Moyle of the Minnesota Department of Conservation in the late 1940's and early 1950's were the first to investigate the blue-green algae blooms in the lake, and to suggest possible causes for the blooms. Moyle suggested that nutrients "especially phosphoric compounds" in the sewage released from the city Detroit Lakes which eventually reached Lake Sallie via the Pelican river and Muskrat Lake, were the likely cause of the nuisance algae blooms.

Findings by the U.S. Geological Survey (USGS) in 1972, and by Dr. Joe Neel of the University of North Dakota (1973) supported the contention that inputs from the Pelican River accounted for the majority of the phosphorus loading to the lake. The USGS study of the hydrologic budget for Lake Sallie found that surface-water accounted for 77% of the total inflow to the lake, and that the Pelican River inflow accounted for almost all of the surface-water sources. Neel's study investigated the impact of weed harvesting on the nutrient dynamics of the lake. He concluded that weed harvesting took out "insignificant amounts of nitrogen and phosphorus with respect to amounts brought in annually by the Pelican River".

Lake Sallie has been th subject of research projec for at least 50 years.

Lake Sallie is featured (the cover of the book: La and Reservoir Restoratio authored by Dr. Dennis Cooke and others.

Given this knowledge, the City of Detroit Lakes installed a tertiary treatment system in 1976 to remove phosphorus from the sewage effluent prior to discharge. Soon after the system was installed, the total phosphorus concentrations in Lake Sallie decreased dramatically from over 100 ppb to a new phosphorus equilibrium of 70 ppb or less. The intensity and frequency of the blue-green blooms also decreased, but some years blooms have produced nuisance conditions.

Although there has been an improvement in the trophic state of Lake Sallie since the 1950s, the lake is still subject to periodic intense summer blue-green algae blooms, and its water quality remains below the norm for lakes in the area.

References that were used to evaluate past nutrient history of the Lake Sallie watershed include:

1948: Moyle, J.B. and J.N. Wilson. Report on the preliminary investigation of the algal growths in lakes in the vicinity of Detroit Lakes. Minnesota Department of Conservation. Invest. Report No. 78.

1951: Moyle, J.B. Report on the investigations of the algal growths in lakes in the vicinity of Detroit Lakes, Minnesota. Minnesota Department of Conservation. Fisheries Research Unit.

1972: Mann, W.B. and M.S. McBride. The hydrologic balance of Lake Sallie, Becker County, Minnesota. U.S. Geol. Survey Prof. Paper, Paper 800-D, pages D-189-D191.

1973: Neel, J.K. Weed harvest and lake nutrient dynamics. EPA Research Project 16010 DFI.

1976: Neel, J.K. Watershed and point source enrichment and lake trophic state index. EPA Project No. R800490.

1976: Bradbury, J.P. and T.C. Winter. Areal distribution and stratigraphy of diatoms in the sediments of Lake Sallie, Minnesota. Ecology 57:1005-1014.

1981: Neel, J.K. Impact of special phosphorus removal procedures in the Upper Pelican River Watershed, Becker County, Minnesota, 1977-80. University of North Dakota, Grand Forks, North Dakota.

1984: Hogen, D.R. Aeration proposal to the Pelican River Board of Managers.

1986: Instrumental Research, Inc. Lake St. Clair marsh treatment/nutrient reduction feasibility study for Pelican River Watershed District.

1993: Hecock, R.D. Diagnostic and feasibility study goals and management alternatives for Lake Sallie and Detroit Lakes Pelican River Watershed.

1994: Hecock, R.D. 1994 Water quality results: a report to Melissa/Sallie improvement association.

1995: Hecock, R.D. Pelican River Watershed District 29th Annual Report.

1996: Hecock, R.D. 1995 water quality: a report to Melissa and Sallie residents.

2. Lake Sallie Diagnostic Study

Watershed and Lake Characteristics
The contributing surface watershed to Lake Sallie is about 58,000 acres (Figure 1 and Table 2). The ratio of the watershed area to lake surface area is about 48:1 (based on a lake surface area of 1,211 acres). The immediate subwatershed (direct drainage) area is about 2,670 acres, and this watershed to lake ratio is 2:1. Lake Sallie is a shallow lake in the sense that is does not thermally stratify throughout the summer. Most of the lake basin is less than 30 feet (Figure 2).

Table 2. Morphological and watershed characteristics of Lake Sallie.

Direct drainage[1]	1,058 hectares (2,670 acres)
Watershed size[2]	23,350 hectares (58,378 acres)
Ordinary high water level	405 meters (1,329 feet) above MSL
Surface area	484 hectares (1,211 acres)
Maximum depth	17 meters (55 feet)
Mean depth	5 meters (17 feet)
Volume	25 x 10 ^{6}m^3 (20,689 ac-ft)
Average annual inflow	27 x 10 ^{6}m^3 (22,000 ac-ft)
Littoral area[3]	208 hectares (520 acres)
Shoreline	9.5 km (5.9 miles)
Maximum length	3.38 km (2.1 miles)
Maximum width	1.77 km (1.1 miles)
Inlets (number)	5
Outlets (number)	1

[1] immediate subwatershed
[2] includes 11 subwatersheds to Sallie plus those that drain to Detroit Lakes
[3] zone between surface and two meter depths

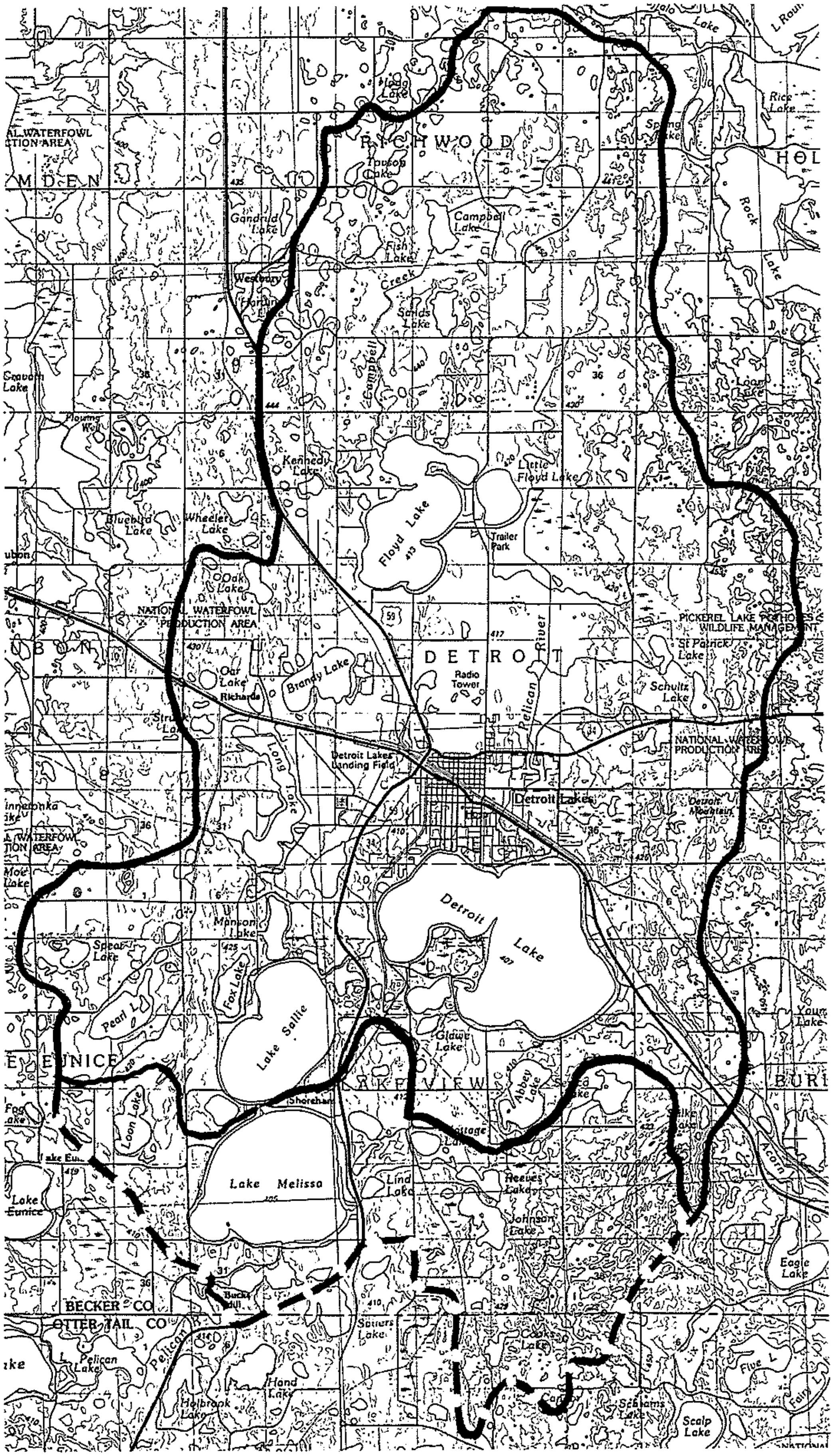


Figure 1. The watershed to Lake Sallie.

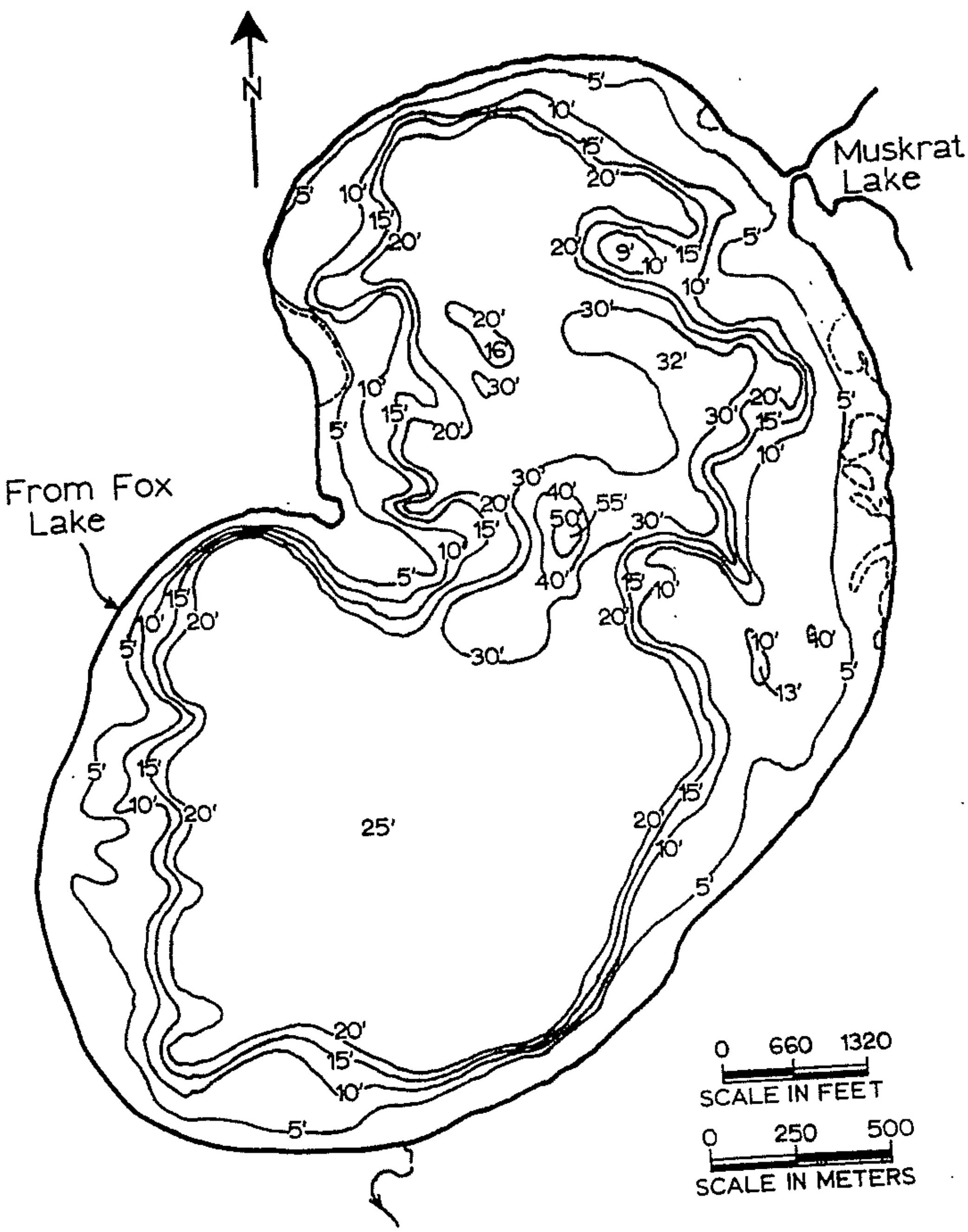


Figure 2. Lake Sallie depth contours.

2.1. Water Quality Data Collected from 1994-1996

Introduction: The Pelican River Watershed District has intensely monitored stream flows and phosphorus concentrations coming into Lake Sallie in 1994, 1995, and 1996 as well as monitoring Lake Sallie. Monitoring station locations are shown in Figure 3. One of the objectives of the monitoring program was to further characterize sources of phosphorus coming into Lake Sallie. Four surface water monitoring stations were active in 1994, 1995 and 1996 and ten shallow groundwater access tubes were installed in the summer of 1996 to characterize flows and phosphorus concentrations in the wetland complex that lies between the Lake St. Clair outlet (SC 3) and the Ditch 14 outlet (SC 4).

Methods -- Surface Water: Four surface water monitoring sites have been established over the years in the vicinity of Lake Sallie as part of a watershed wide water quality monitoring network (Figure 3). Although additional sites are located in the upper watershed. For this Phase I update we concentrated on monitoring the four sites: St. Clair Lake outlet (SC 3), Ditch 14 outlet (SC 4), Little Detroit Lake outlet (PR 6), and the Muskrat Lake outlet (PR 7).

Additional details on methods are found in the 1993 diagnostic report (Hecock 1994) and from a research paper by R. Nustad (1996).

Three sites (SC 3, SC 4, and PR 7) have continuous flow recorders. Water samples have been collected every two weeks, and sometimes more frequently. The watershed model FLUX has been used to calculate daily flows and nutrient loads. Site characteristics are shown in Figures 4, 6 and 7.

Methods -- Groundwater: Wetland discharges to Ditch 14 (referred to as Ditch D in this report) were characterized by installing ten groundwater wells at five locations in the wetland complex (Figure 3). Site characteristics are shown in Figure 5. Groundwater wells were sampled on ten occasions from June through September.

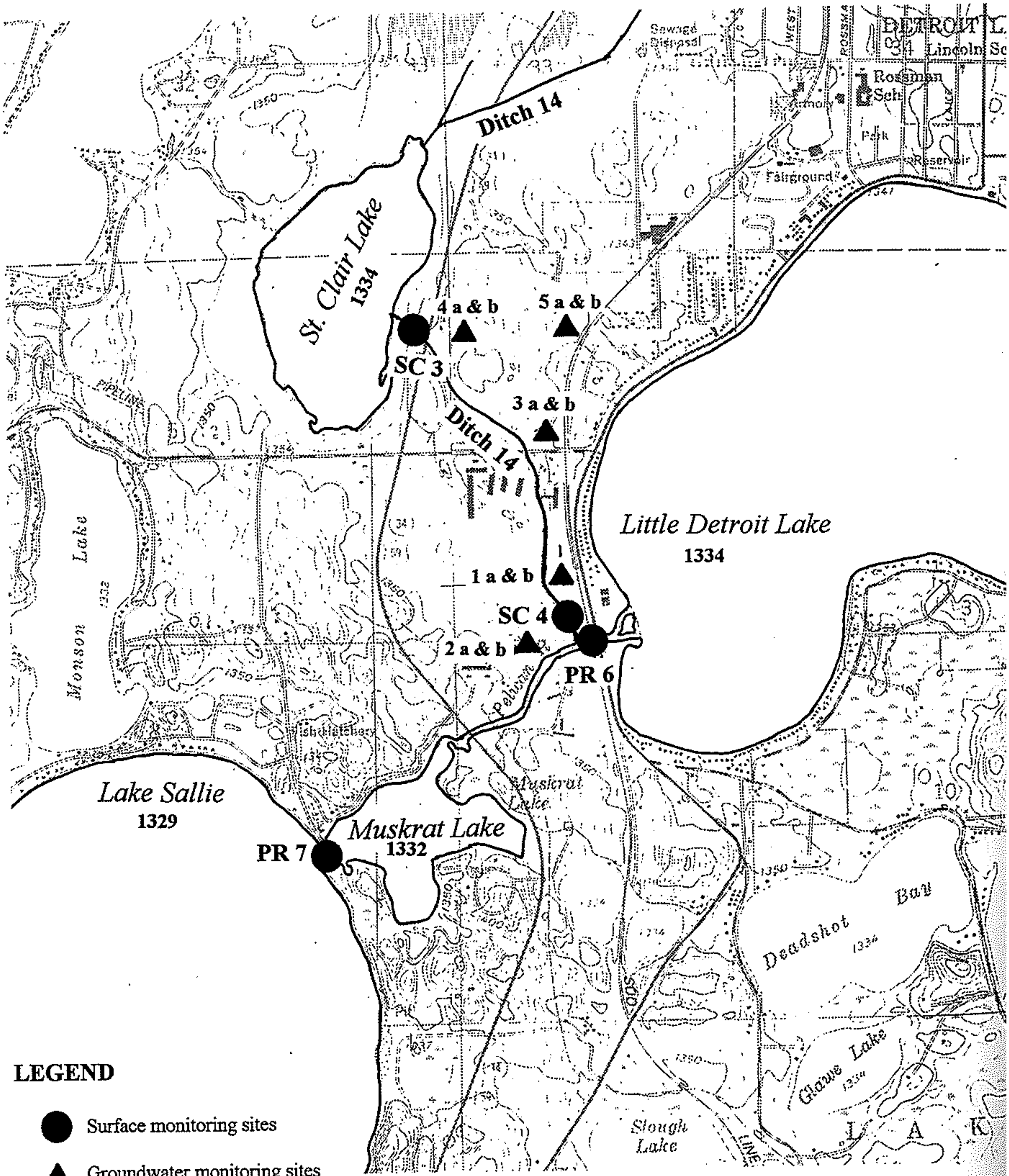


Figure 3. Surface water monitoring stations for 1994, 1995, and 1996.

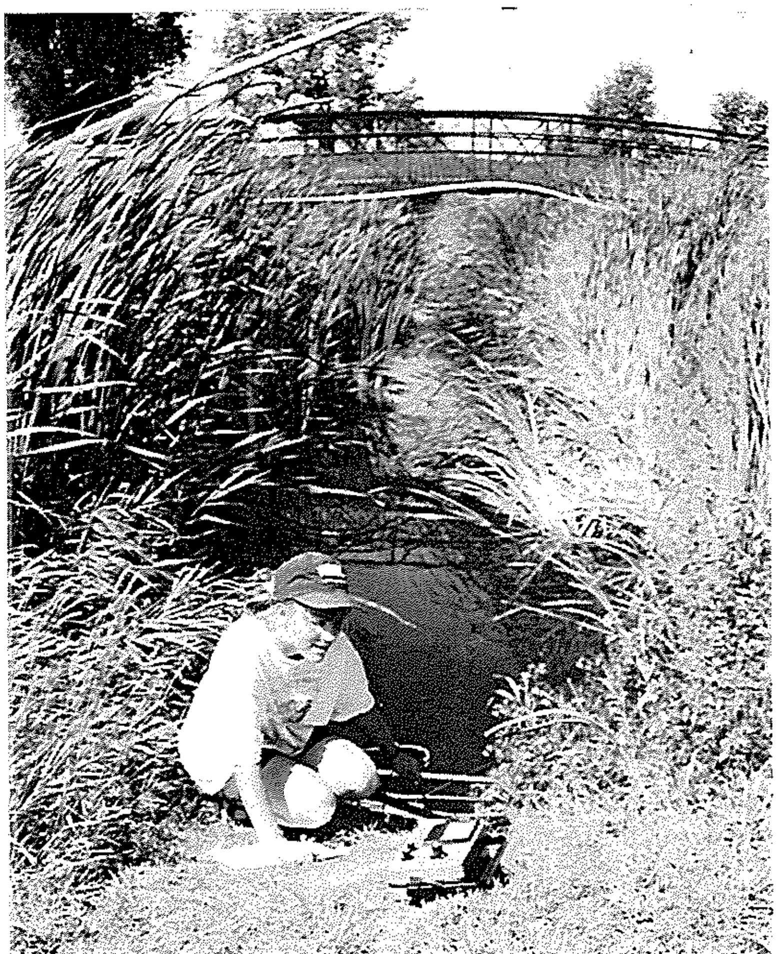


Figure 4. [top] St. Clair Lake is in the background. [bottom] St. Clair Lake outlet (SC 3) sampling site. This stream flows into Ditch 14.

Figure 5. [top] Ten 'wells' were installed in a wetland complex that has been bisected by Ditch 14. Access points went three to four feet into the ground. Water was pumped from the wells and analyzed for TP, OP, and/or iron. Pump tests were also conducted to determine hydraulic conductivity. Rochelle Nustad, Bemidji State University, is shown installing and sampling the groundwater. Discharge to Ditch 14 from these wetlands was referred to as "Ditch D".

Figure 6. Tim James, MPCA, checks the flow level recorder at the outlet of Ditch 14 (SC 4).

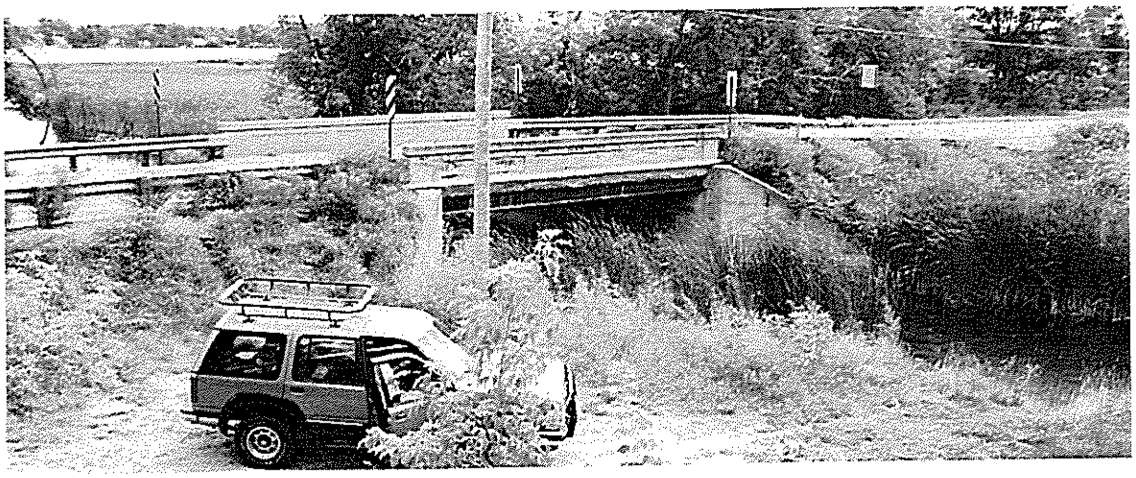


Figure 7. [top] The outlet of Little Detroit Lake flows under the bridge and is referred to as the Pelican River at this point. This is also a monitoring station, PR 6.
[bottom] The Pelican River (PR 6) is met with the Ditch 14 outflow (SC 4) and the mixed flow enters Muskrat Lake. The outlet from Muskrat Lake (PR 7) is the Dunston Locks. One of the locks (no longer operable) is shown here.

Results: Summary of Watershed Monitoring Data for 1994-1996

Surface water monitoring has been ongoing in a systematic way since 1994 for a number of stations in the watershed. A summary of weekly flows, phosphorus concentrations, and phosphorus loadings for 1996 are shown in Table 3. Weekly data for 1994 and 1995 data are shown in Appendix A. Descriptions of the surface water monitoring stations are:

SC 3: outlet from Lake St. Clair that flows into Ditch 14
SC 4: outlet of Ditch 14 that flows into the Pelican River
PR 6: outlet of Little Detroit lake, prior to the confluence with Ditch 14.
PR 7: outlet of Muskrat Lake at the Dunston Locks.

Over the years it has been observed that flow and phosphorus concentrations increase from the SC 3 station to the SC 4 station. It was suspected that groundwater discharge to Ditch 14 was largely responsible for this increase. Groundwater research in the summer of 1996 confirmed this. Therefore, a station referred to Ditch D (ditch discharge) has been created which is based on calculating the difference in flows and phosphorus loading from SC 3 and SC 4.

The picture that emerges is that Lake St. Clair discharges high phosphorus loads over spring and then there is a decline through summer. The wetland discharge to Ditch 14 seems to increase during the summer.

SC 3, the Lake St. Clair outlet, seems to have a spring loading peak and then it declines through the summer (Figure 8). Ditch D loading peaks in midsummer (Figure 9). The loading from the outlet of Ditch 14 (SC 4) which represents loading influences from SC 3 and Ditch D shows a bi-modal curve (Figure 10) representing inputs from SC 3 in spring and Ditch D over the summer.

Phosphorus loading from the outlet of Little Detroit Lake (PR 6) is variable over spring and summer (Figure 11) but generally less than Ditch 14 (SC 4) even though flows are higher out of Detroit Lake (Appendix A and D). Phosphorus concentrations in PR 6 are generally less than 40 ppb.

The Pelican River flows into Muskrat Lake and represents contributions from Ditch 14 (SC 4) and Little Detroit Lake (PR 6). In addition, in-lake processes such as sedimentation and sediment nutrient release, influence lake phosphorus concentrations and phosphorus loadings to Lake Sallie. The highest weekly loadings to Lake Sallie from Muskrat Lake (recorded at Dunston Locks -- PR 7) are in spring and early summer (Figure 12).

Table 3. 1996 Lake Sallie Watershed water quality data.

Weeks	SC 3 (Lake St. Clair Outlet to Ditch 14) Flow (cfs)	SC 3 Conc (ug/l)	SC 3 Load (lb/wk)	Ditch D (Wetland Outlet to Ditch 14 Est) Flow (cfs)	Ditch D Load (lb/wk)	SC 4 (Ditch 14 Outlet) Flow (cfs)	SC 4 Conc (ug/l)	SC 4 Load (lb/wk)	PR 6 (Detroit Lake Outlet to Pelican River) Flow (cfs)	PR 6 Conc (ug/l)	PR 6 Load (lb/wk)	PR 7 (Muskrat lake Outlet to Dunston Locks) Flow (cfs)	PR 7 Conc (ug/l)	PR 7 Load (lb/wk)	SC 4 + PR 6 (est) Load (lb/wk)
Jan 1	4.8	80	14.6	–	–	–	–	–	–	–	–	–	–	–	
2	4.8	88	16.2	–	–	–	–	–	27.5	10	4.6	31.7	12	8.4	20.8
3	4.8	112	20.6	–	–	–	–	–	–	–	–	0	0	0	20.6
4	6.2	133	47.9	–	–	–	–	–	41.2	15	19.9	28.6	23	10.5	67.8
Feb 1	7.0	162	42.3	–	–	–	–	–	29.5	18	8.6	24.0	39	10.0	50.9
2	6.0	199	44.5	–	–	–	–	–	24.8	25	13.0	29.0	49	52.2	57.5
3	4.4	226	37.0	361 –	–	–	–	–	16.8	25	9.0	30.0	54	61.2	46.0
4	3.9	226	39.0	–	–	–	–	–	13.7	24	8.9	25.8	58	15.9	47.9
Mar 1	5.5	240	50.0	–	–	–	–	–	20.3	23	12.4	0	0	0	70.3
2	4.5	282	48.9	–	–	–	–	–	17.8	29	19.3	22.6	88	32.2	68.2
3	3.5	286	36.8	2.9	39.3	6.4	275	76.1	15.4	36	21.0	24.8	86	80.3	97.1
4	4.1	247	56.6	2.3	24.1	6.4	235	80.7	17.3	40	37.5	29.1	69	107.8	118.2
Apr 1	5.0	228	42.3	6.9	66.2	11.9	238	108.5	18.9	30	21.0	30.9	83	100.0	129.5
2	8.9	206	66.4	4.6	83.1	13.5	295	149.5	27.3	30	30.8	40.3	124	189.6	180.3
3	11.6	199	87.2	3.4	39.2	15.0	238	126.4	44.0	32	53.3	59.3	95	206.3	185.7
4	11.3	196	107.2	3.7	12.2	15.0	164	119.4	54.8	29	77.7	73.5	59	210.2	197.1
May 1	9.4	166	59.1	3.9	-13.0	13.3	91	46.1	55.2	20	42.5	72.4	36	99.1	88.6
2	6.8	119	30.6	5.3	16.7	12.1	103	47.3	51.8	21	40.6	70.5	40	106.0	87.9
3	7.3	102	28.0	8.0	52.6	15.3	137	80.6	68.4	23	61.0	74.6	36	99.9	141.6
4	6.4	82	28.7	9.0	114.1	15.4	172	142.8	68.5	25	90.6	81.6	39	171.4	233.4
Jun 1	5.4	72	14.8	6.3	70.3	11.7	191	85.1	55.0	30	63.1	69.7	47	123.2	148.2
2	5.3	88	17.5	6.4	112.2	11.7	296	129.7	52.4	32	63.4	64.9	51	123.8	193.1
3	4.1	93	14.5	5.1	93.0	9.2	306	107.5	44.6	15	26.1	52.0	45	88.2	133.6
4	3.7	95	16.6	3.2	74.4	6.9	271	91.0	34.7	10	16.4	41.5	41	82.8	107.4
Jul 1	2.8	108	11.4	2.3	35.0	5.1	241	46.4	24.5	19	17.2	32.1	45	53.6	63.[illegible]
2	2.4	115	10.2	1.3	17.8	3.7	174	28.0	17.0	28	17.8	23.6	56	49.6	45.[illegible]
3	2.1	109	7.5	1.3	13.3	3.4	162	20.8	11.8	31	13.6	20.6	58	45.7	34.[illegible]
4	1.6	112	9.4	1.1	7.5	2.7	169	16.9	9.3	29	14.7	15.5	49	40.7	31.6
Aug 1	1.6	105	6.4	1.4	17.5	3.0	147	23.9	11.0	26	10.5	17.8	42	28.2	34.[illegible]
2	1.3	109	6.1	1.3	6.9	2.6	131	13.0	8.2	18	5.8	14.7	32	18.0	18.[illegible]
3	1.2	95	4.3	0.8	7.7	2.0	157	12.0	3.4	12	1.4	8.0	28	8.5	13.[illegible]
4	1.0	87	4.9	0.8	13.6	1.8	190	18.5	0.8	20	1.0	4.8	34	8.4	19.[illegible]
Sep 1	1.2	94	4.4	1.2	11.8	2.4	177	16.2	4.3	28	4.6	12.4	40	18.6	20.[illegible]
2	1.2	120	5.2	0.9	6.6	2.1	149	11.8	2.2	23	2.0	9.6	42	14.9	13.[illegible]
3	1.0	132	5.0	0.5	5.6	1.5	154	10.6	0	7.6	0	1.9	51	3.4	10.[illegible]
4	1.3	139	8.7	0.9	7.6	2.2	156	16.3	0	30	0	6.8	60	20.5	16.[illegible]
Mar 3 - Sept 4 →			690		948			1625			734			2099	236[illegible]

Handwritten bracket totals: 96 (PR 6 Load, Jan 2 – Mar 2); 190 (PR 7 Load, Jan 2 – Mar 2); 450 (SC 4 + PR 6 Load, Jan 2 – Mar 2).

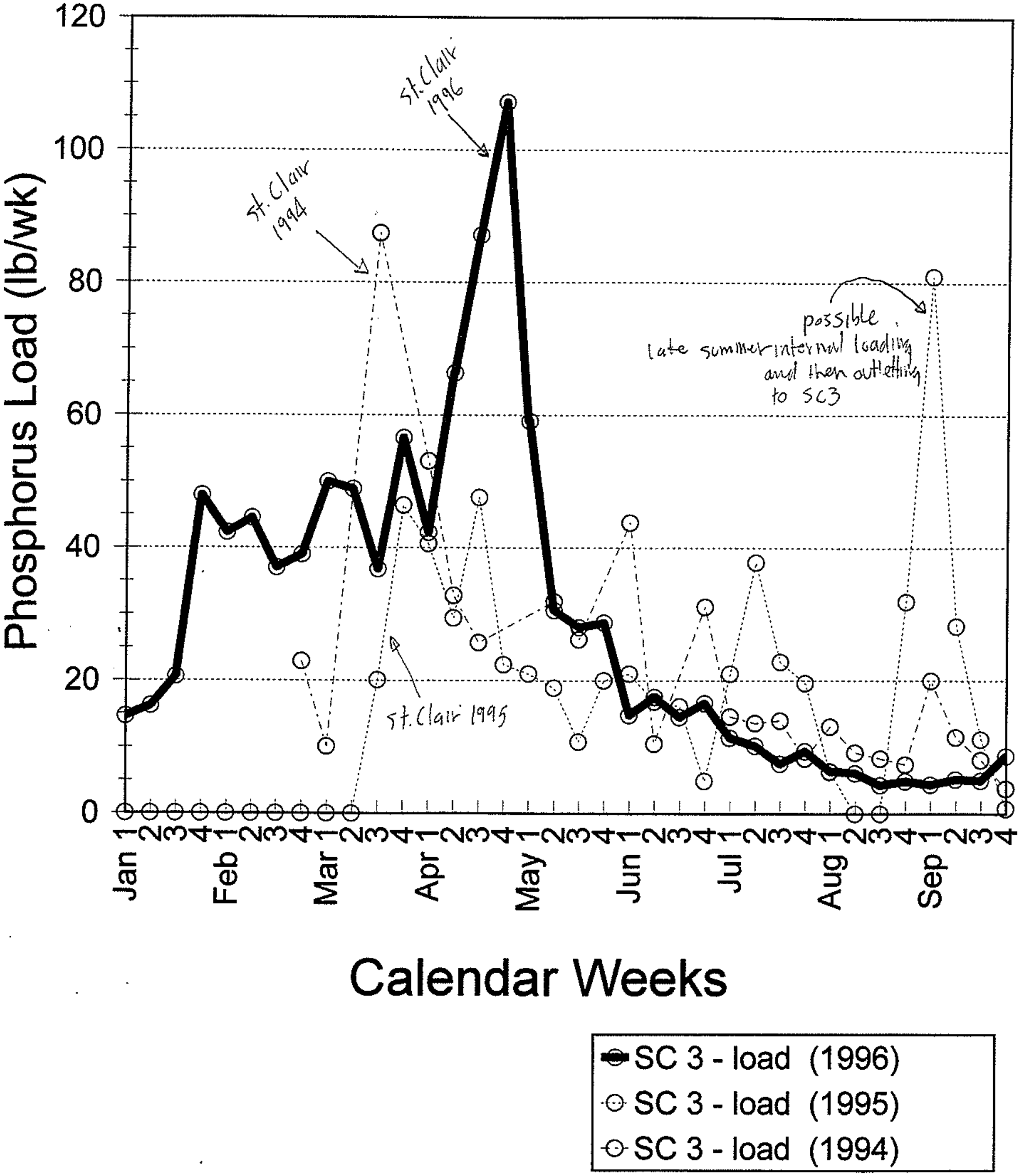


Figure 8. Phosphorus loads for Lake St. Clair outlet for 1994, 1995, and 1996. In 1994 and 1996 spring phosphorus loads were substantial compared to summer loading.

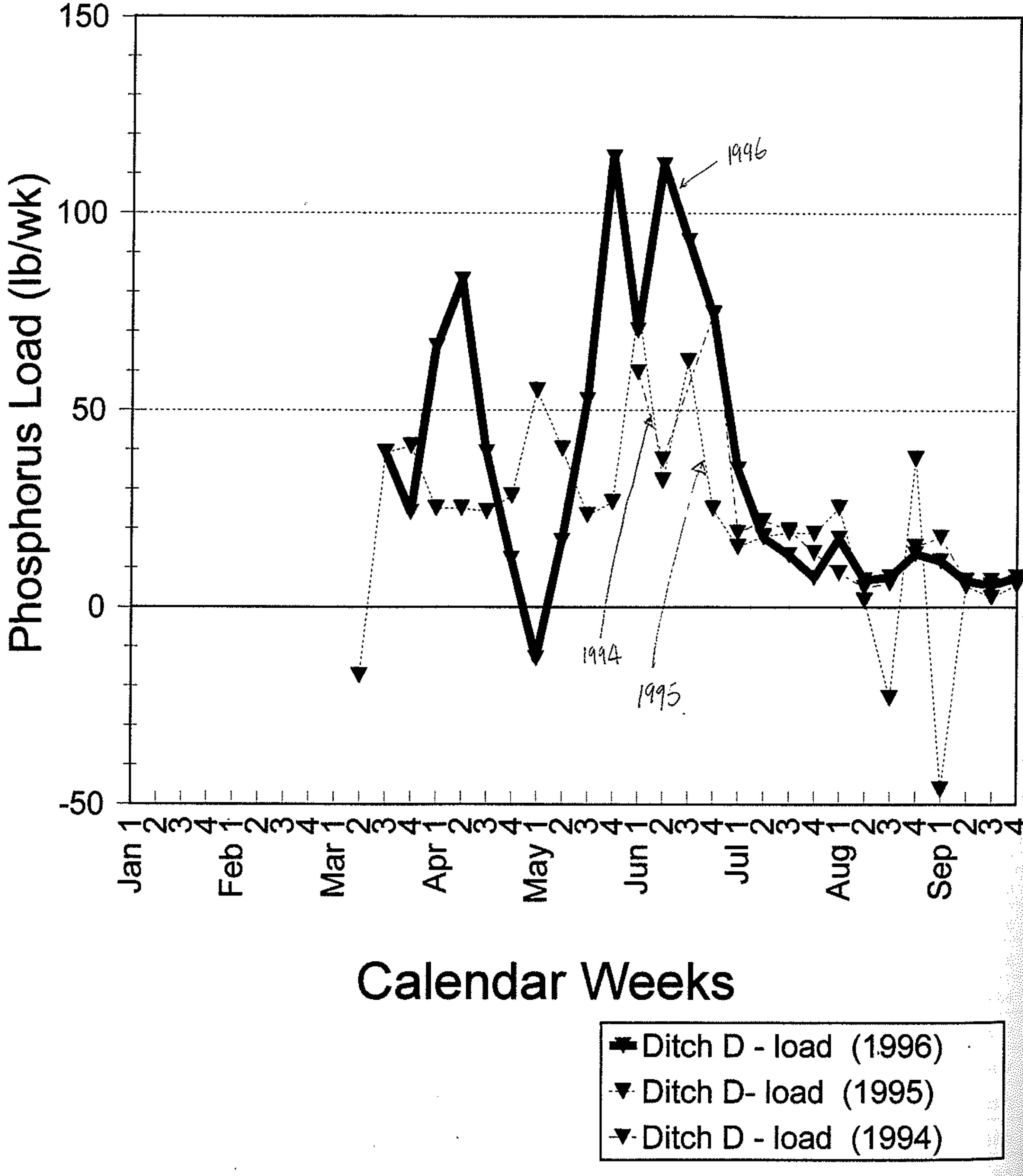


Figure 9. Phosphorus loads for the wetland discharge to Ditch 14 for 1994, 1995 and 1996. In 1996, phosphorus loads peak in May and June. These loads were calculated by subtracting weekly SC 3 loads from SC 4 loads.

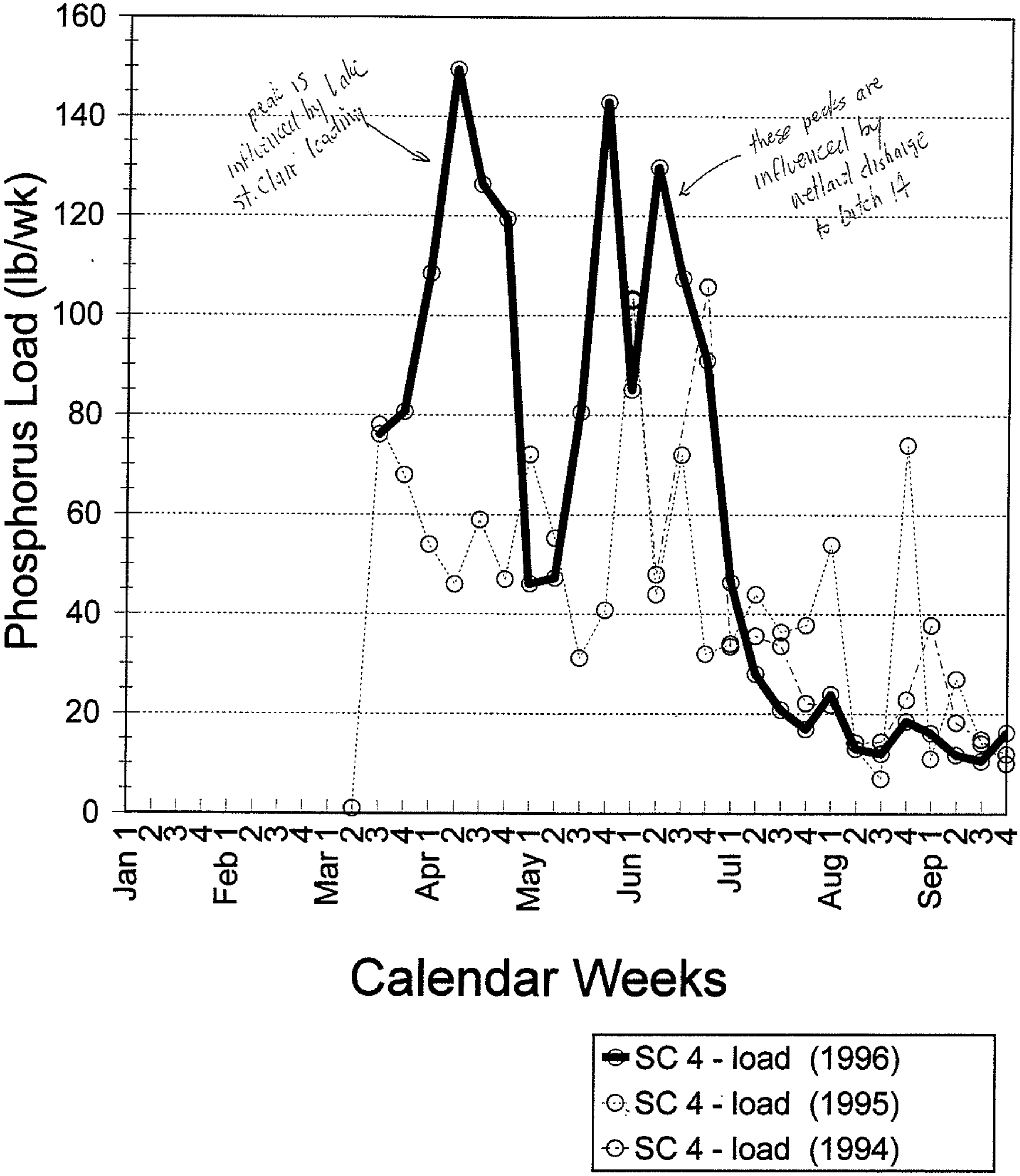


Figure 10. Phosphorus loads for the Ditch 14 discharge (SC 4) for 1994, 1995, and 1996. In 1996, a bimodal peak is found.

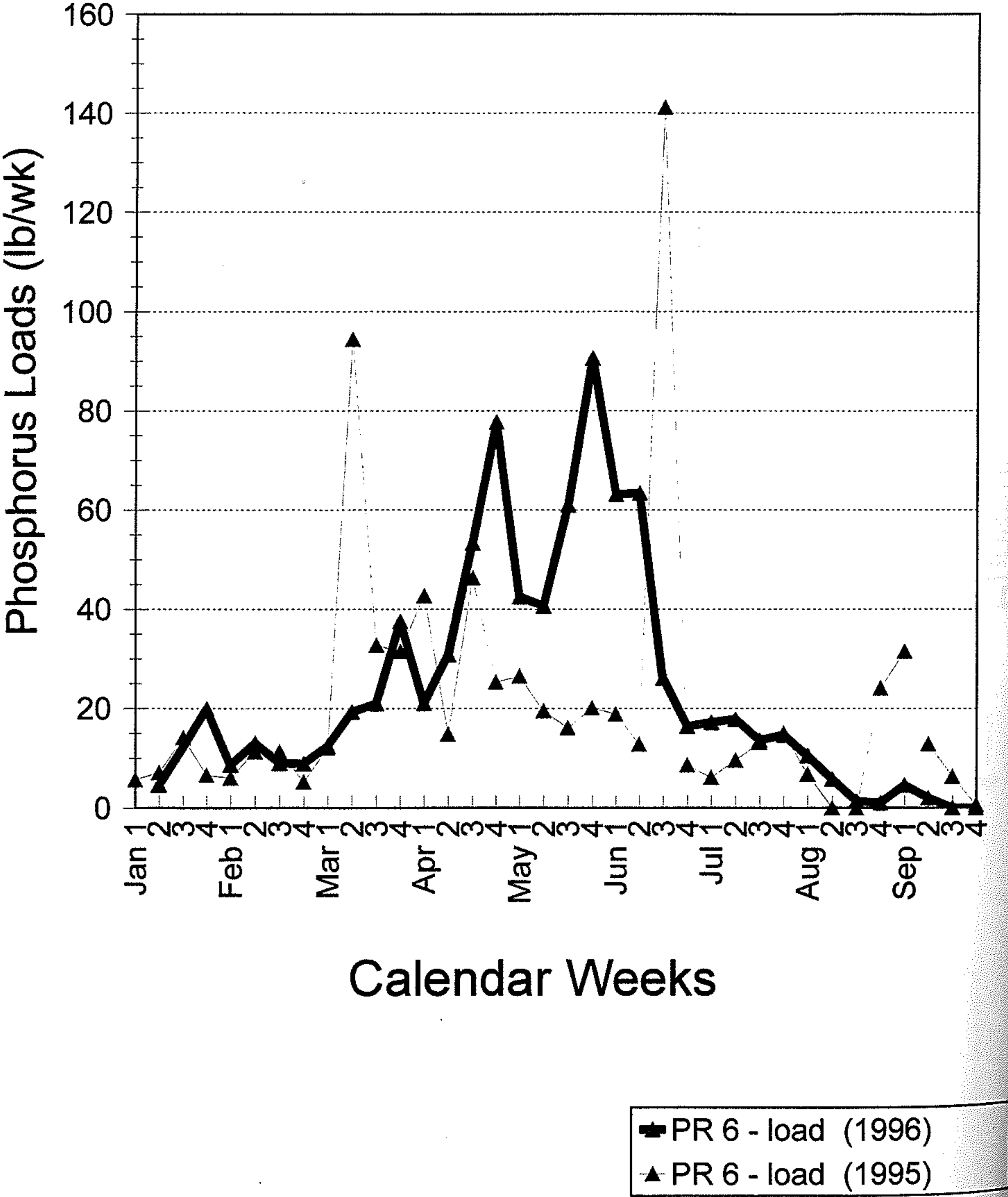


Figure 11. Phosphorus loads for the Little Detroit Lake outlet (PR 6). Loads in 1996 were higher than in 1995. Two peaks in 1995 may represent artificially high loads due to sampling artifacts.

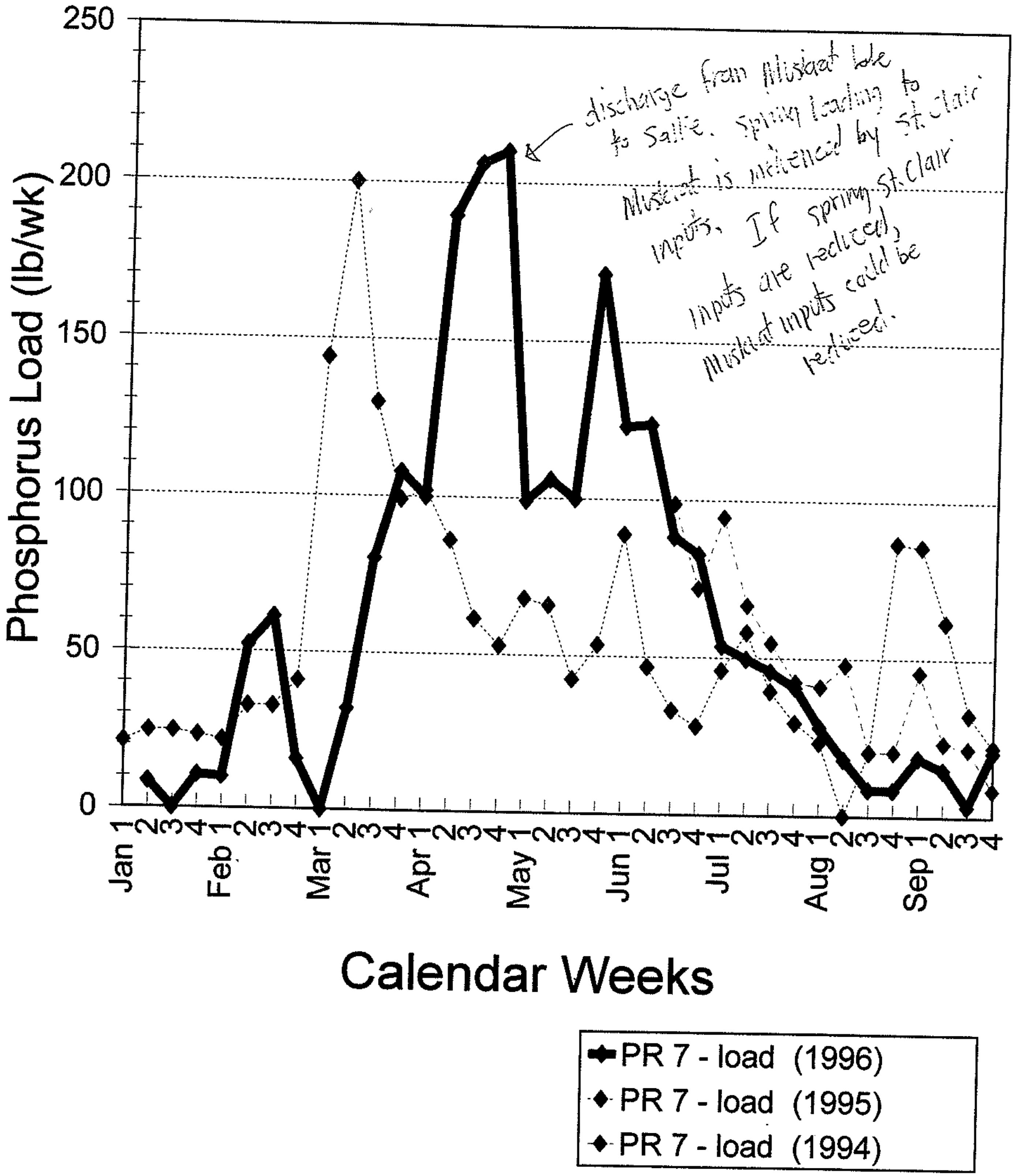


Figure 12. Phosphorus loads for the Muskrat Lake outlet (PR 7) in 1994, 1995, and 1996. The peak inflow into Lake Sallie in 1996 was about six weeks later than it was in 1995.

Results: Summary of Lake Sallie Monitoring Data for 1995 and 1996

Trophic Indicators: Lake Sallie continues to show a wide range of secchi disc transparencies over the growing season with several weeks out of the summer especially problematic. Lake Sallie trophic indicators for 1996 are listed in Table 4. Up until the end of June, clarity was good and algae (as expressed by chlorophyll) was low. Through July and August, water transparency dropped to around five feet or less and algae was increasing.

This sequence of decreasing water clarity over the summer has been occurring over the last decade, with some years being worse than others.

FLUX and BATHTUB modeling has helped to sort out the magnitude of internal loading in Lake Sallie.

Internal loading varies from year to year.

Bruce Wilson and Mark Evenson, MPCA, have been instrumental in conducting the modeling.

Dissolved Oxygen and Internal Loading: In 1996, internal loading was probably not significant based on bottom phosphorus concentrations that were not excessively high (Table 4) compared to other lakes and based on the presence of dissolved oxygen in bottom waters for most of the summer. In lakes with significant phosphorus release, bottom phosphorus concentration often over 200 ppb. The one high reading of 86 ppb - OP in Lake Sallie (Table 4) seems to correspond to the one episode during the summer when dissolved oxygen was low in Lake Sallie (Figure 13). In 1995, low dissolved oxygen conditions in bottom water of Lake Sallie appeared to last longer compared to 1996 (Figure 14). Internal loading was also estimated to be more significant in 1995 (based on BATHTUB and FLUX runs, Appendix D).

Table 4. Lake Sallie water quality for 1996. TP=total phosphorus, OP=ortho phosphorus, and Chl a=chlorophyll a.

Date	Secchi Disc (ft)	TP (ug/l)	OP (top) (ug/l)	OP (bottom) (ug/l)	Chl a (ug/l)
May 22	7.5	49	5		7
May 29	13.6		41		4
May 30	13.5	33			
June 7	20.9	31	10	16	13
June 14	15.8				
June 18	13.0	23	11	22	
June 20	15.0				2
June 28	12.0	5	9	21	4
July 2	7.9	25	9	28	8
July 15	5.4	36	5	84	6
July 25	4.5		21		9
July 30	3.5	15	10	38	21
Aug 7	4.0	43	12	53	23
Aug 15	3.0	38	18	46	43
Aug 20	4.0	193	3	10	53
Aug 28	3.0	49	5	12	29
Sept 10	3.5	62	18	13	41
Sept 18	5.5	52	10	9	

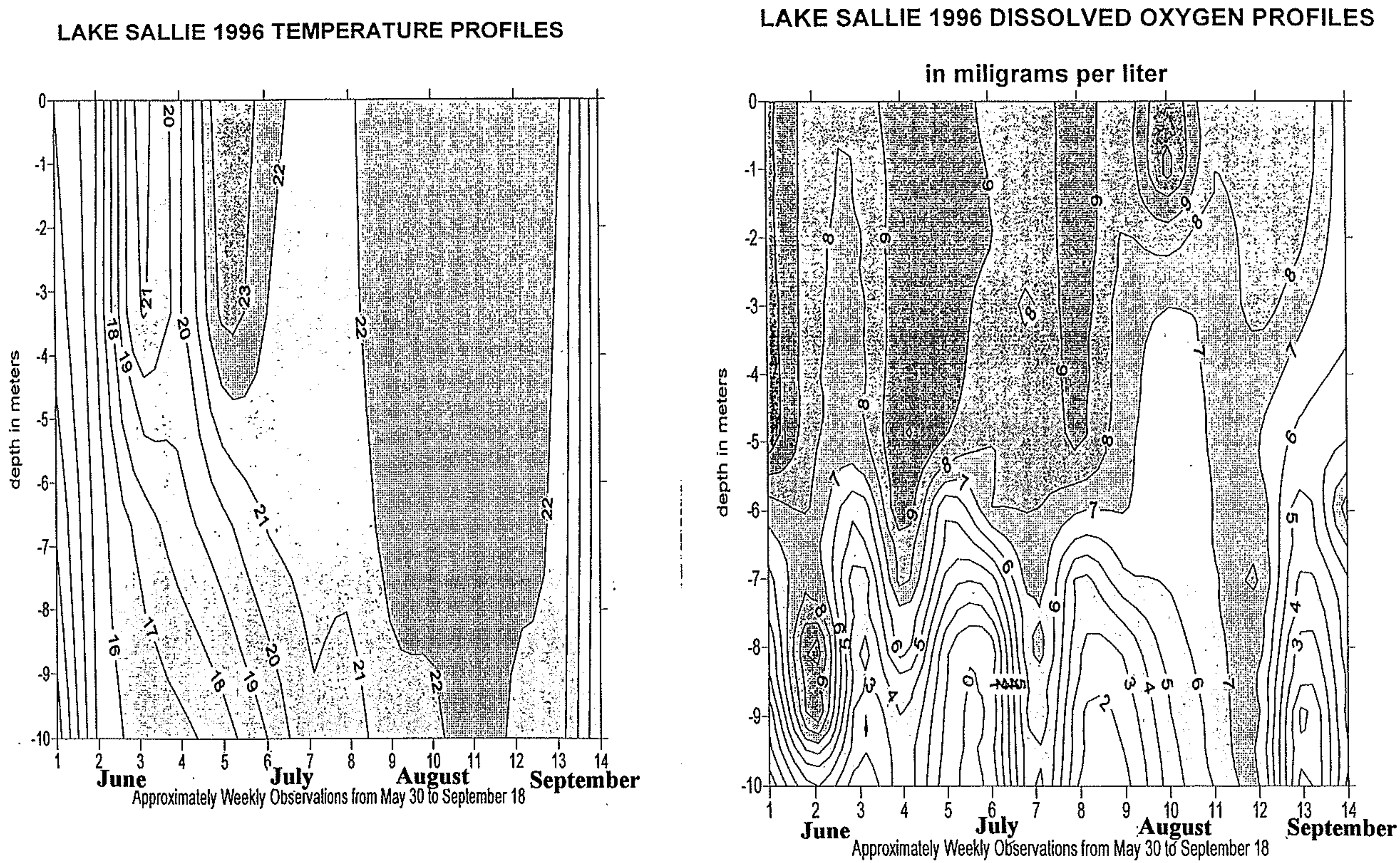
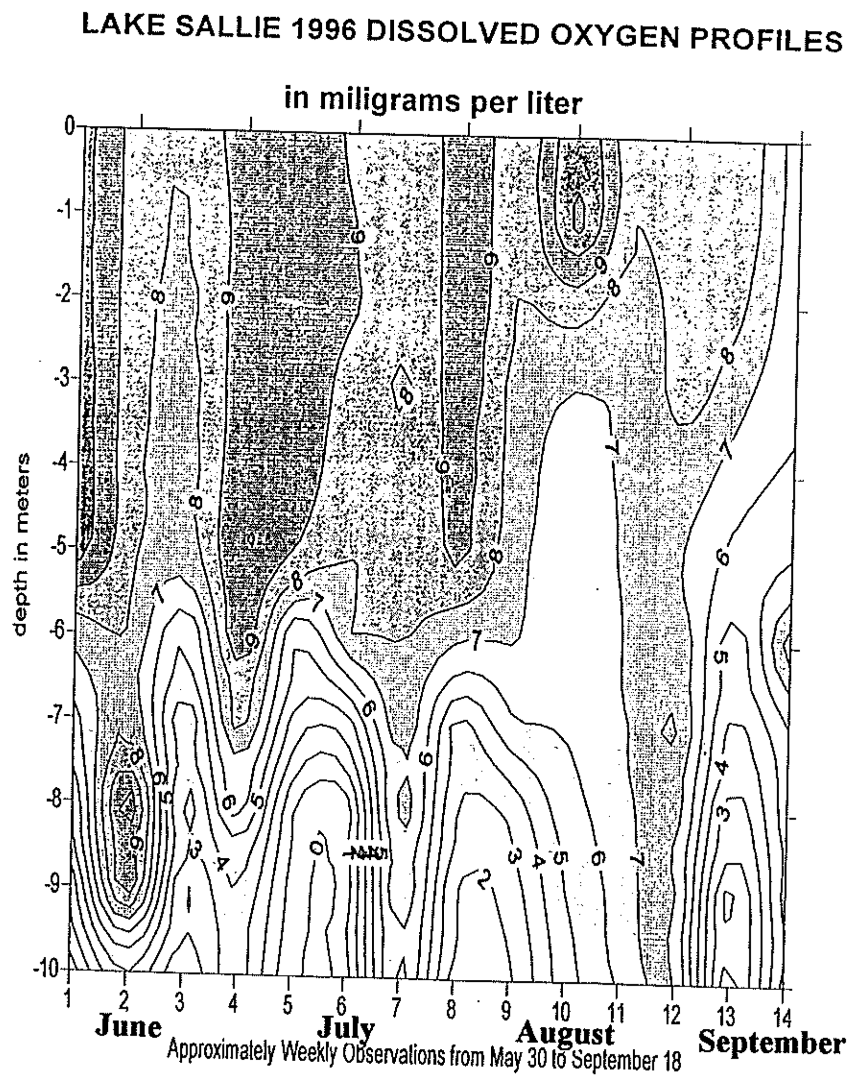


Figure 13. Temperature and dissolved oxygen profiles in Lake Sallie in 1996.



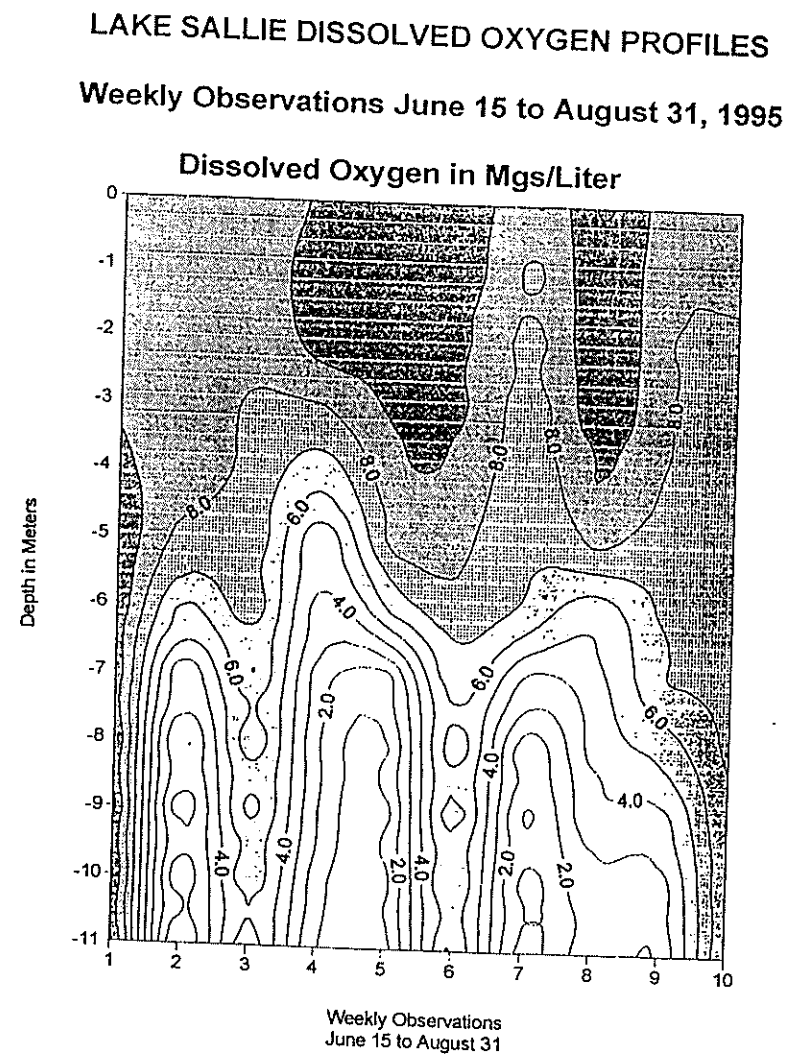


Figure 14. Comparison of dissolved oxygen profiles in Lake Sallie in 1996 and 1995.

Lake Sediments: Two Lake Sallie sediment samples were collected in the summer of 1996 and were analyzed using standard agricultural soil test methods. Phosphorus results indicate that lake soils are highly fertile with Olsen phosphorus concentrations of 28 ppm (Table 5). Agricultural soils are considered fertile when phosphorus readings are over 15 ppm. These phosphorus concentrations represent available phosphorus and are only a fraction of the total phosphorus in the sediments. However, comparing Lake Sallie results to other lake soil sediment analyses, the Lake Sallie sediments have a high potential for phosphorus release (McComas, unpublished).

Lake soil analysis using agricultural soil testing methods gives a broad indication of soil fertility. Test results show Lakes Sallie and Muskrat have highly fertile soils.

Two Muskrat Lake samples were also collected and analyzed. Olsen phosphorus concentrations are also elevated in Muskrat Lake, indicating a high phosphorus release potential in Muskrat Lake as well.

Table 5. Sediment chemistry for Lake Sallie and Muskrat Lake.

Field	Bray P	Olsen P	Exch K	Zinc	Sulfur	Iron	Copper	Manganese	Boron	Organic	K		Ca		Mg		Na		CE[illegible]
Ident	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	Matter	ppm	Bsat	ppm	Bsat	ppm	Bsat	ppm	Bsat	me[illegible]
Muskrat	4	27	64	1.4	52	69	1.56	52	3.5	9.0	32	0.4	2920	76	487	21	105	2.4	[illegible]
Muskrat 1	6	26	57	1.0	39	50	1.48	42	3.4	9.0	28	0.4	2720	76	452	21	86	2.1	[illegible]
Muskrat 2	4	25	63	1.0	51	63	1.48	43	3.4	9.0	31	0.4	2720	75	480	22	98	2.4	[illegible]
Sallie 1	4	28	90	1.4	111	200	12	71	3.9	10	45	0.6	2840	72	585	25	119	2.6	[illegible]
Sallie 2	3	28	98	1.3	131	200	7.64	65	3.9	11	49	0.7	2720	73	547	24	97	2.3	[illegible]

2.2. Sources of Lake Sallie Nutrients

Nutrient inputs to Lake Sallie come from direct and indirect sources. In some years spring phosphorus loading from Muskrat Lake is high (as it was in 1995) and other years it is lower (like in 1996)(Table 6). A summary of phosphorus loading, broken down by season is shown in Table 6.

Table 6. Phosphorus loading in pounds from watershed sources in 1995 and 1996.

	Jan 1 - Mar 14		Mar 15 - Sept 30		TOTAL (Jan 1 - Sept 30)	
	1995	1996	1995	1996	1995	1996
SC 3 (Lake St. Clair outlet)	21	361	563	690	584	1,151
Ditch D (wetland discharge)	0	--	673	948	673	948+
SC 4 (Ditch 14 outlet)	1	--	1,167	1,625	1,167	1,625+
PR 6 (Detroit Lake outlet)	174	96	583	734	757	830
SC 4 + PR 6 (inflow to Muskrat Lake)	176	450	1,750	2,365	1,925	2,815
PR 7 (outflow from Muskrat Lake to Lake Sallie)	566	190	1,464	2,099	2,030	2,289

Internal phosphorus loading in Lake Sallie is also a factor in most years. Internal Lake Sallie phosphorus loads for 1994, 1995, and 1996 are shown in Figure 5. Loads were calculated based on watershed inputs and on the observed Lake Sallie phosphorus concentration. When running a lake model, if watershed phosphorus inputs did not produce a predicted lake phosphorus concentration, then internal loading inputs were assumed to make up the difference. A summary of phosphorus loading to Lake Sallie for 1988, 1995, and 1996 is shown in Table 7. Loading estimates for 1995 and 1996 were based on FLUX and BATHTUB modeling results (run by Bruce Wilson, MPCA).

Details of the FLUX and BATHTUB runs are shown in Appendix D.

Table 7. Estimated phosphorus budget for Lake Sallie.

Source	1988 (kg - P/yr)	1995 (kg - P/yr)	1996 (kg - P/yr)
Pelican River	**371**	342	691
Lake St. Clair + Ditch 14		972	1,523
Monson and Fox Lakes subwatersheds	7	7	7
Groundwater	116	0	0
Atmosphere	110	121	121
Internal Loading	1,700	3,536	0
TOTAL	2,304	4,978	2,342

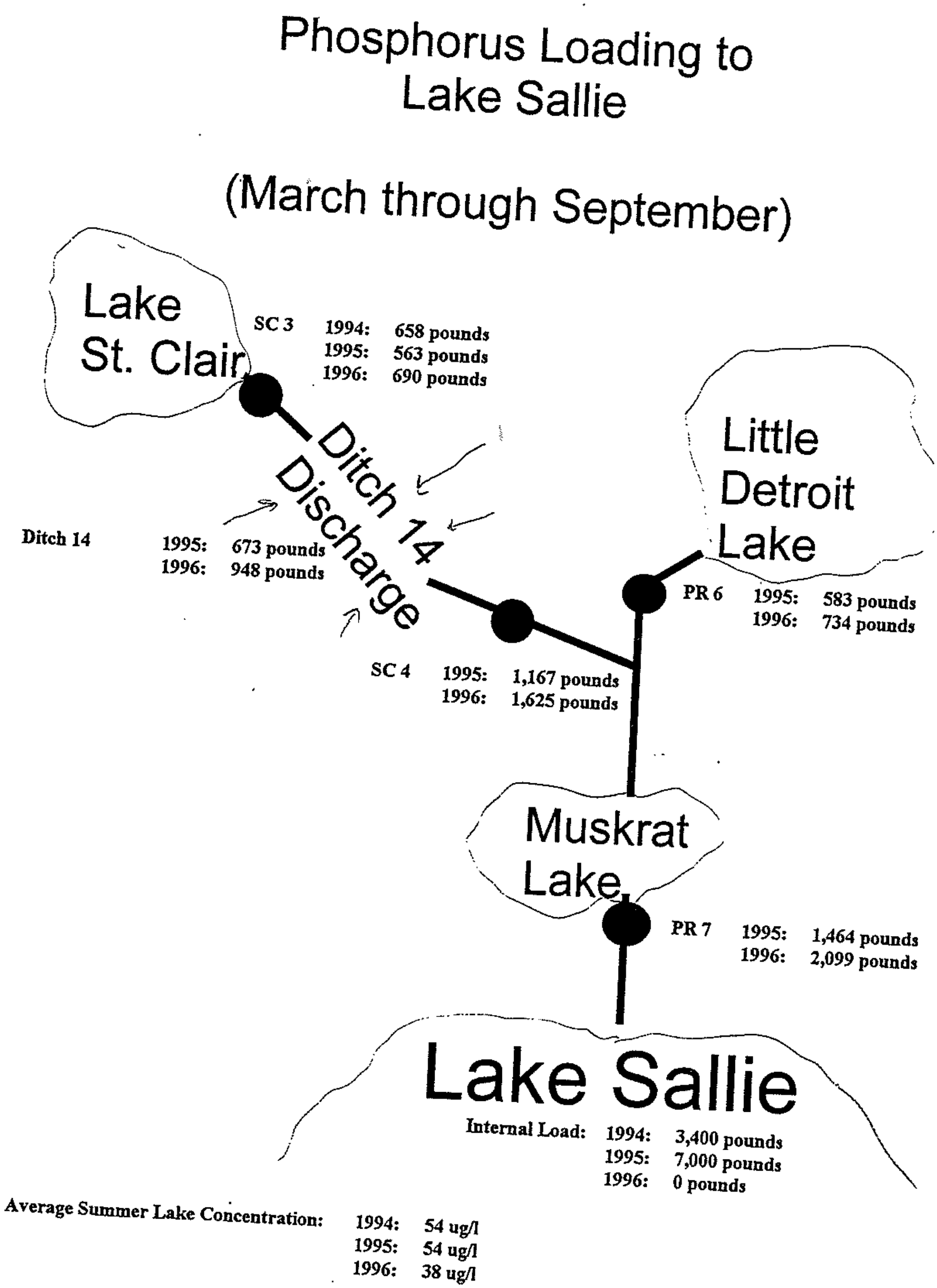


Figure 15. Phosphorus loading to Lake Sallie from several sources for the period of March through September.

Nutrient loading sources to Lake Sallie are very dynamic in the sense they are subject to drastic changes. Phosphorus loading sources vary seasonally, from spring through summer and fall, and yearly, where in one year there may be a big load and the next year it is much lower. Nutrient loading to Ditch 14 for 1996 shows a seasonal loading condition (Figure 16). The Lake St. Clair outlet (SC 3) has high spring loads, and lower mid-summer loads, whereas the wetland discharge (Ditch D) peaks in mid-summer.

Another system that acts in a dynamic manner is Muskrat Lake. It can be a source or a sink of phosphorus to Lake Sallie. In 1996, it served as a sink. An estimated 2,815 pounds of phosphorus entered Muskrat Lake based on the combined loads of Ditch 14 (SC 4) and Little Detroit outlet (PR 6), but only 2,289 pounds left (from Table 6 -- Jan-Sept 1996). Weekly inflow and outflow loads for Muskrat Lake are shown in Figure 17. Muskrat Lake was a sink in early spring and in mid-summer. It was a source for a couple of weeks April and in July. In 1995, Muskrat Lake showed no clear cut net retention or exportation of phosphorus, that is, inputs nearly equaled outputs (Table 6).

These watershed dynamics coupled with climatic conditions probably influences the degree of internal phosphorus release from Lake Sallie, but the mechanisms are speculative at this time.

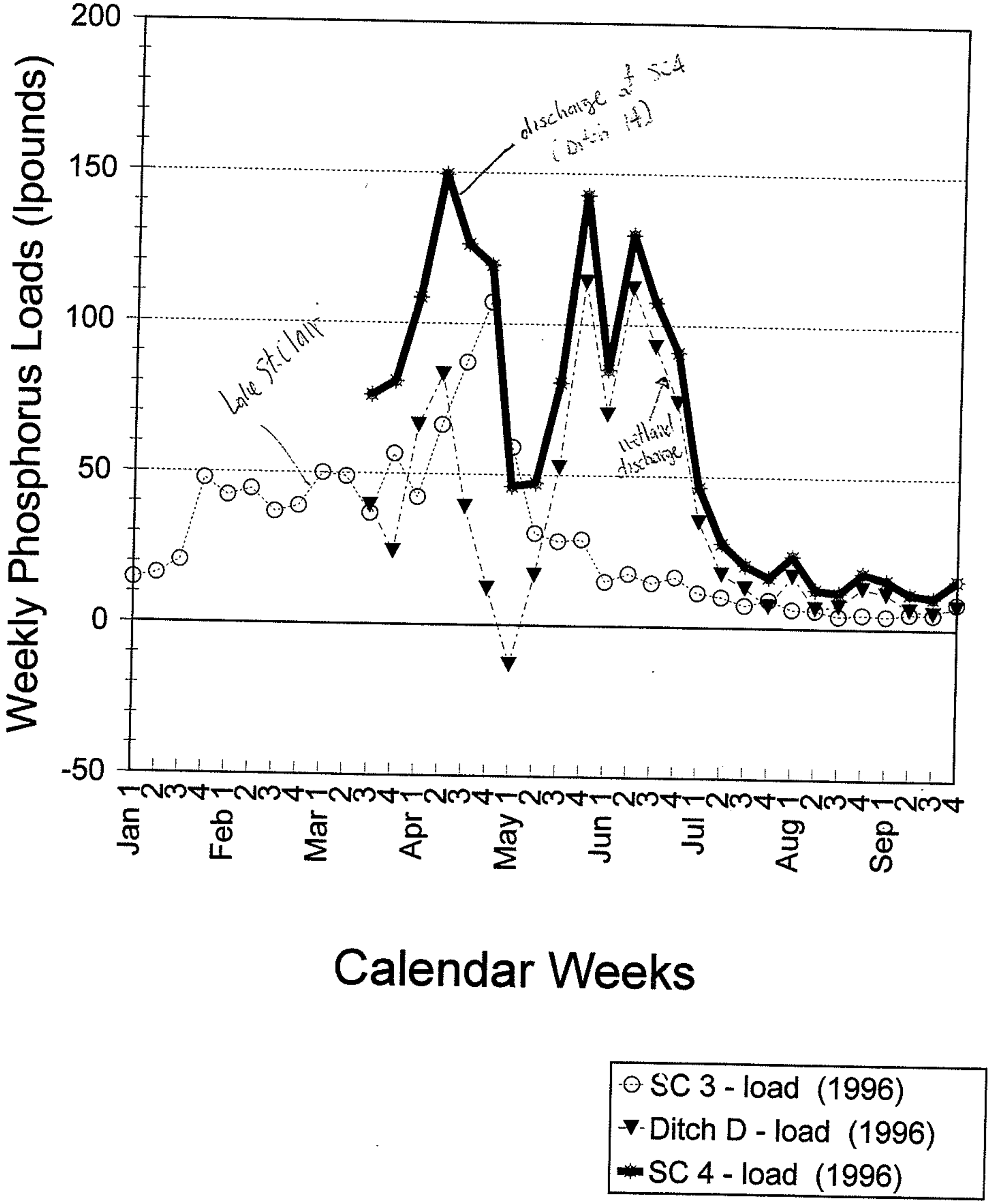


Figure 16. Weekly phosphorus loads to Lake Sallie for 1996. In spring, Lake St. Clair loading (SC 3) is important, but in summer, Ditch D loading (wetland discharge) represents a significant phosphorus loading.

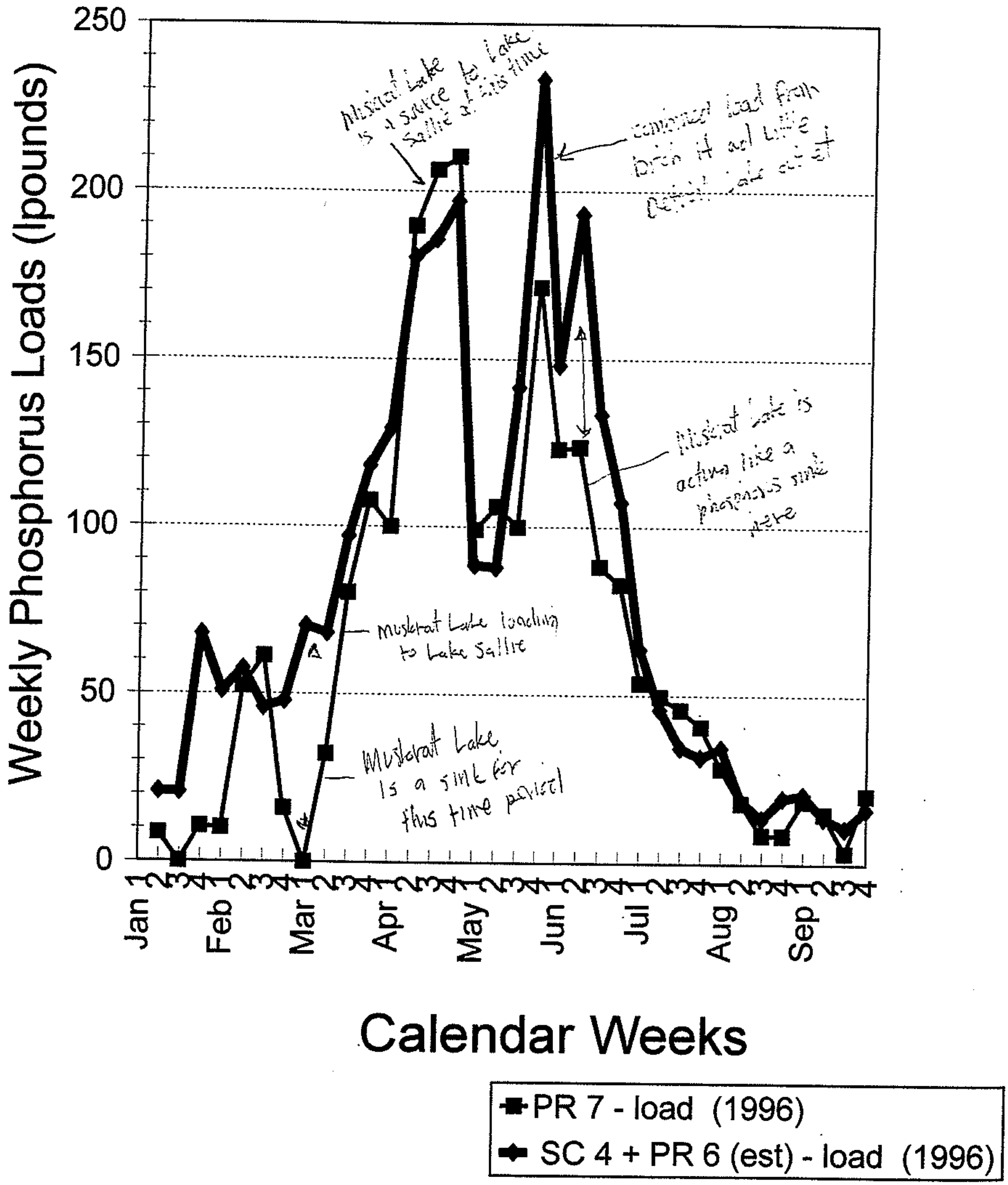


Figure 17. Muskrat lake can act as a sink or a source of phosphorus to Lake Sallie. In 1996, it served as a sink. An estimated 2,815 pounds of phosphorus came into Muskrat Lake and an estimated 2,289 pounds left, going to Lake Sallie (from Table 6). Muskrat Lake is a sink when SC 4 + PR 6 (inflows) are greater than the outflow (PR 7) loads.

2.3. Water Quality Trends in the Watershed and in Lake Sallie

Watershed Trends

Big changes have occurred in the Lake Sallie watershed and in Lake Sallie over the last 150 years. The watershed and lakes were probably in a natural undisturbed condition in the 1850s when land surveyors first came through and officially mapped the area. Many of the features found in the 1850s are still found today. A U.S. Land Office Survey map from the 1850s is shown in Figure 18. The basic lake outlines for Detroit and Sallie indicate water levels haven't changed much. An outlet stream from Little Detroit is present, and a small Muskrat Lake is also delineated. The size of Muskrat Lake increased when the Dunston Locks were installed.

Lake St. Clair has actually gotten smaller. Ditch 14 probably drained some of the lake, creating the present day basin configuration.

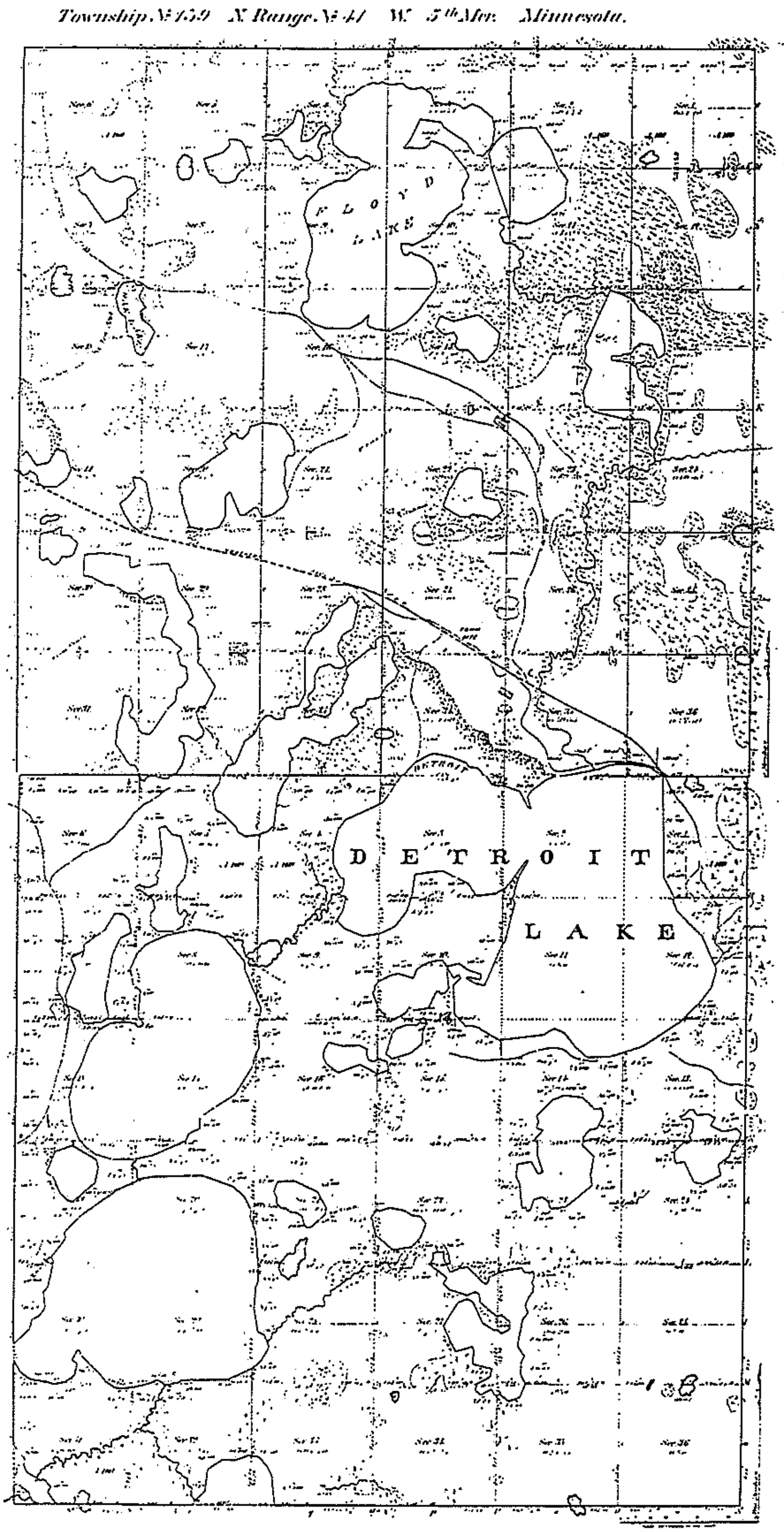


Figure 18. **Land Office survey for the Lake Sallie watershed area, conducted in the 1850s.**

Lake Sallie and Detroit Lake basin configurations haven't changed much from the 1850s. Muskrat Lake has gotten bigger (due to the Dunton Locks) and Lake St. Clair has gotten smaller (due to draining by Ditch 14). Outlet streams from Lake St. Clair and Detroit Lake appear to be natural.

Watershed Phosphorus Inputs to Lake Sallie -- Influence of Lake St. Clair: It's been known since the 1950s that wastewater treatment plant discharges have been enriching the watershed and Lake Sallie (Moyle and Wilson 1948). Subsequently, Lake Sallie experienced nuisance algae blooms.

Wastewater treatment plant operations changed in 1976, and phosphorus inputs to Lake St. Clair were drastically reduced. Phosphorus export from Lake St. Clair is lower in the 1990s than the 1970s (Table 8).

Phosphorus export from Lake St. Clair has declined significantly since the 1970s, but is still a factor in the phosphorus load to Lake Sallie.

Table 8. Historical phosphorus loading from St. Clair outlet (Hecock 1993 for 1968 - 1988; This study for 1995 and 1996).

Years	St. Clair Outlet (pounds)	St. Clair phosphorus as % of Total P load to Sallie
1968-70	11,071	--
1973	12,770	82.4%
1974	9,648	61.0%
1974	9,533	62.6%
1978-79	9,385	43.2%
1979-80	2,543	64.5%
1988	213	57.3%
1995	584	40%
1996	1,151	49%

Source: Neel 1971, 1973, 1978, 1982; 1988 data from stream samples

Watershed Phosphorus Inputs to Lake Sallie -- Influence of Detroit Lake: The outlet from Little Detroit Lake represents a huge watershed contributing flow and phosphorus to Lake Sallie. The water quality in Detroit Lake appears to be at ecoregion levels and is stable (Figure 19). No trends are apparent at this time.

Detroit Lake needs ongoing protection to maintain good water quality. If water quality in Detroit Lake deteriorates, Lake Sallie water quality will be adversely impacted as well.

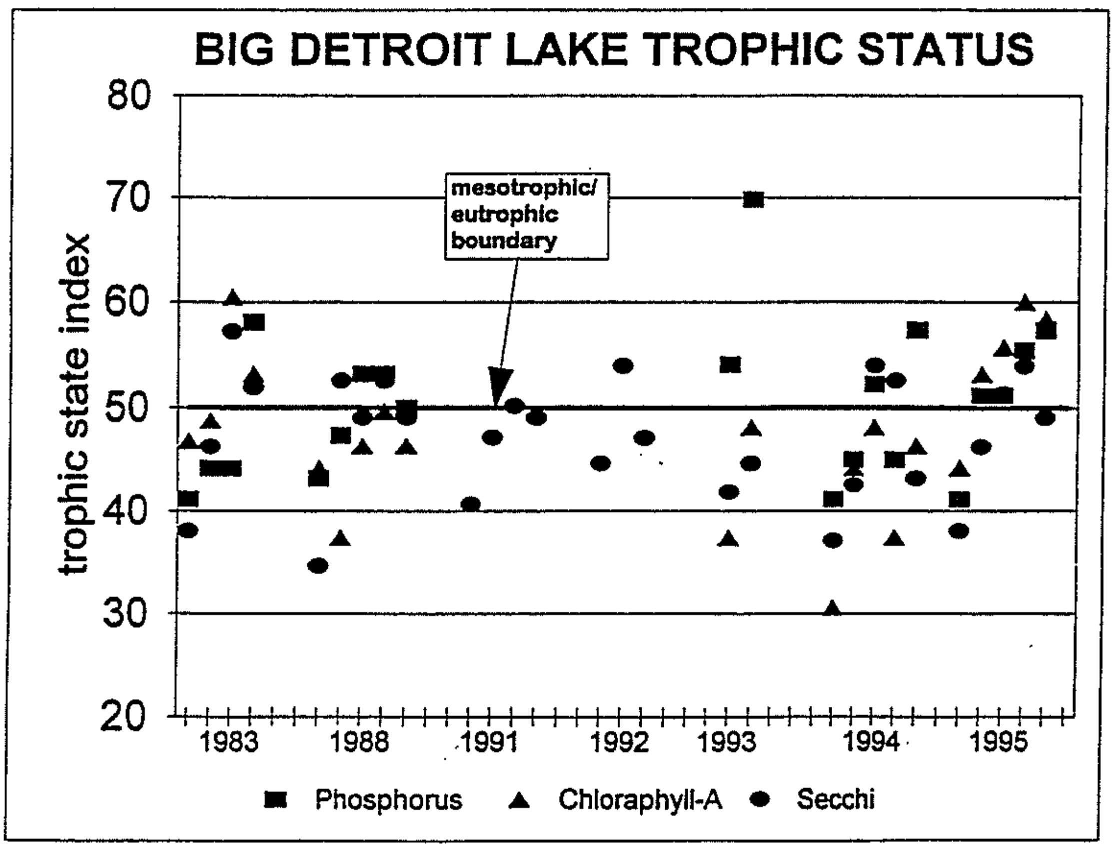


Figure 19. Trophic state indicators for Detroit Lake, since 1988 (from Hecock 1995).

Lake Sallie Trends

Secchi Disc Transparency: Monitoring data before 1988 is sparse but written comments in DNR files and newspaper articles going back to the 1940s describe nuisance algae blooms in Lake Sallie. In 1988, and then picking up again in 1994, secchi disc readings have been taken through the growing season (May - September). In general Lake Sallie has shown wide swings in water transparency with the clearest water in early summer and the most turbid water in late fall. The secchi disc trend data are not sufficient to draw conclusions about improving or degrading lake conditions (Table 10). However, the minimum secchi disc readings of two to four feet that still occur indicate a substantial algae bloom condition for at least part of the summer.

Wide swings in water transparency are found during the growing season in Lake Sallie. In 1996, water transparency peaked at 21 feet and had a summer low of 3 feet due to an algae bloom.

Table 10. Lake Sallie secchi disc transparency.

Date	Summer Average	Summer Range	Number of Readings
8.4.49	13.7	--	n=1
6.17.68	6.0	--	n=1
9.4.85	5.0	--	n=1
1988	5.8	2-9.6	n=9
1994	8.2	4-18	n=14
1995	6.5	2-16	n=13
1996	8.0	3-20.9	n=18

Lake Sallie Phosphorus Concentrations: The change in the phosphorus concentration in Lake Sallie after upgrading the Detroit Lakes Wastewater treatment plant to tertiary treatment in 1976 was dramatic. Lake sampling in 1980 showed a much lower summer average compared to previous lake sampling results (Table 10).

It appears that Lake Sallie has a lower summer phosphorus equilibrium concentration compared to the 1970s. However the summer range of phosphorus concentrations show that there are readings high enough to produce nuisance algae blooms.

Lake phosphorus concentrations are trending downward. Proposed projects will be designed to consistently keep phosphorus levels low in Lake Sallie.

It is hard to determine how long it would take Lake Sallie phosphorus concentrations to return to averages that are comparable to other lakes in the area. However, estimates for some lakes are on the order of 30 years or more (Chapra and Canale 1991).

Table 11. Lake Sallie phosphorus data (surface water).

	Phosphorus (ug/l)		
	Summer Mean	Summer Range	Samples
1968 (Mn DC)	170	--	1
1968 (Neel, 1973)		50-230	12
1969 (Neel, 1973)		30-750	31
1970 (Neel, 1973)		60-1440	32
1971 (Neel, 1973)	400	10-920	14
1973 (Neel, 1978)	150	90-250	14
1974 (Neel, 1978)	160	130-200	14
1975 (Neel, 1978)	350	230-480	14
1978 (Neel, 1981)	502	320-750	14
1980 (KV, 1980)	60	30-93	8
1983 (Hogan, 1983)	46	20-107	4
1988 (Hecock, 1993)	54	23-79	10
1989 (Hecock, 1993)	23	18-27	2
1994 (Hecock, 1994)	54	11-71	4
1995 (Hecock, 1995)	52	15-100	12
1996 (this study)	36	15-65	14

Lake Sallie Internal Loading: Data from lake monitoring efforts over the past twenty years, and insights from lake modeling suggest that a legacy of the many years of sewage inputs is influencing the poor water quality in Lake Sallie. The nutrient-enriched sediments that accumulated during the sewage treatment era, appear to release phosphorus which likely fuels the blue-green blooms during the summer stratification period.

Internal loading of phosphorus from the sediments occurs when oxygen is depleted from the hypolimnion in the summer. Under these conditions, a chemical reaction occurs in which iron-phosphorus compounds in the sediments are broken down and phosphorus is released into the water column and is available for uptake by algae.

Data from 1988 and 1995 are consistent with the belief internal loading is fueling the blue-green blooms in Lake Sallie. The 1996 data do not strongly imply significant internal loading. For these years, there is an extensive data set of temperature, dissolved oxygen, (Figure 20) and total phosphorus concentrations which provide a mechanistic pattern for the onset of anoxia and the internal release of phosphorus. In each instance, the onset of anoxia in the hypolimnion is concurrent with dramatic increases in the total phosphorus concentrations in the hypolimnion. Lake Sallie tends to periodically mix during the summer, and this mixing distributes the phosphorus throughout the water column where it can be taken up by algae in the photic zone.

The key to reducing significant internal loading in Lake Sallie will be to keep the oxygen demand low in the water column and in the sediments which may allow oxic conditions throughout the water column.

These data suggest that year to year variability in the lake's stratification pattern may determine the intensity of the blue-green blooms.

For example, in 1988, the lake thermally stratified in mid-May, and soon thereafter the water below 7 m was virtually devoid of oxygen [< 0.2 mg/l (Figure 20)]. This corresponded to a dramatic increase in total phosphorus concentrations in the hypolimnion (Hecock 1993), strongly suggesting sediment release of phosphorus. The lake's thermal stratification broke down in late June and phosphorus in the hypolimnion was circulated throughout the water column in mid-July. From that point onward, blue-greens dominated the phytoplankton, secchi disk transparency was three feet or less, and chlorophyll a concentrations increased eight-fold (from 2.4 mg/l on 8 June to 18.6 ug/l on 7 July).

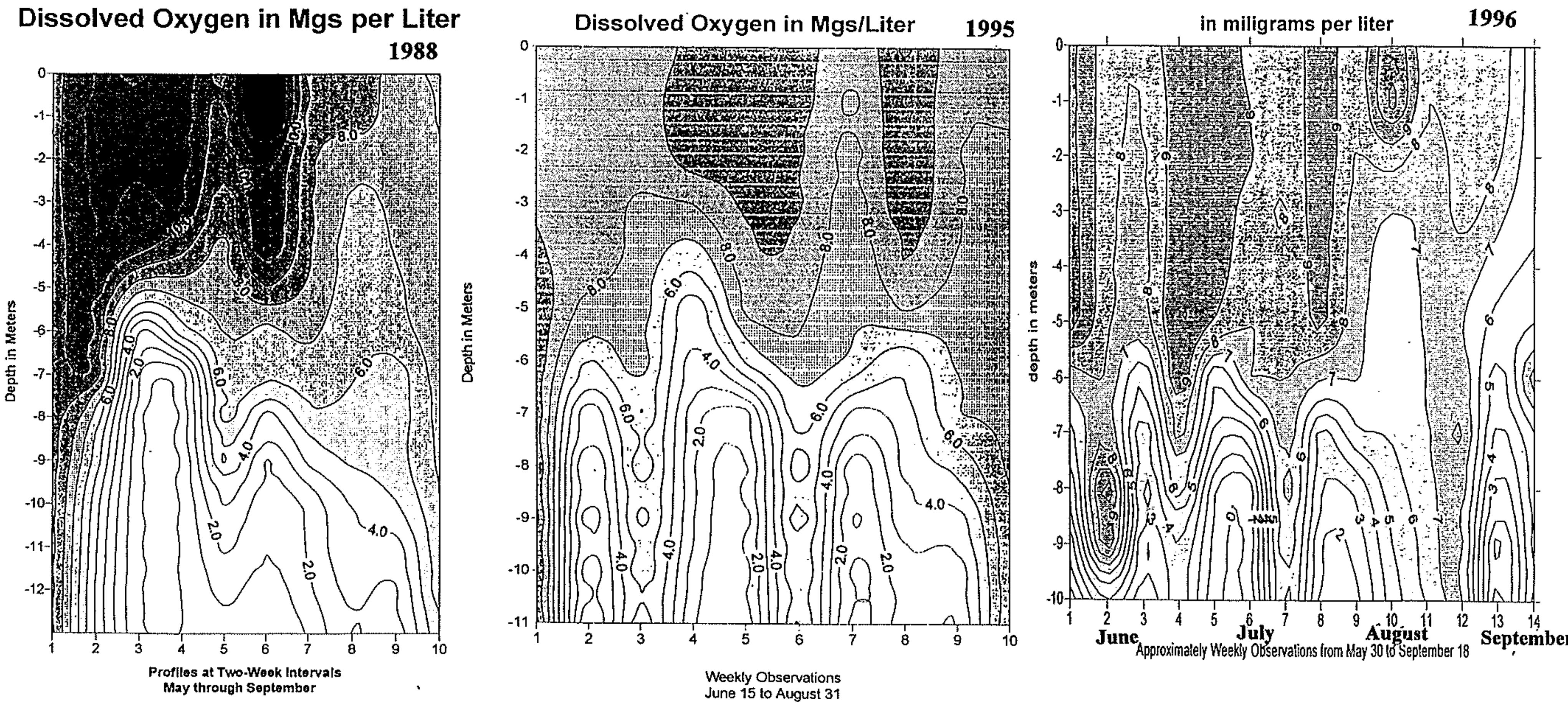


Figure 20. Dissolved oxygen distribution in Lake Sallie over the growing season for 1988, 1995, and 1996.

In 1995, hypolimnetic anoxia didn't occur until mid-July. Subsequently, total phosphorus concentrations were relatively low (< 40 ug/l) until this point and then rapidly increased and remained high (> 75 ug/l) from late July through August. Not surprisingly, the period from mid-July through August was when the blue-green blooms were most severe and secchi depths ranged from 2-4 ft. A similar pattern, but reduced in scale was found in 1996.

No consistent trend is apparent at this time. The cause for anoxic conditions in the hypolimnion of Lake Sallie are probably related to temperature, spring inflows and wind action.

Lake Sallie Fish: The fish community in Lake Sallie appears to show water quality improvements based on black and yellow bullhead ratios. A summary of raw fishery data is shown in Table 12.

Table 12. Historical abundance of selected fish species in Lake Sallie (from Hecock 1993, and based on MnDNR fish survey data).

	Number of Fish Per Net Per Year					
Species	**1949**	**1968**	**1975**	**1981**	**1984**	**1989**
White Sucker	3.8	3.5	2.5	4.2	2.9	3.4
Black Bullhead	3.7	101.2	11.0	22.5	1.6	7.6
Yellow Bullhead	0.2	0.1	0	1.7	0.3	2.0
Brown Bullhead	1.0	2.3	0.9	0.7	0.4	1.6
Bluegill	--	4.1	1.6	4.5	5.2	30.4
Yellow Perch	42.0	38.8	25.0	48.0	70.4	52.5
Walleye	16.3	5.8	3.0	9.3	3.8	3.3

Dennis Schupp of the MnDNR has been using black to yellow bullhead ratios as a water quality indicator for some time (Schupp and Wilson 1993). The smaller the ratio the better the relative water quality is (meaning the fewer black bullheads to yellow bullheads the better). This ratio has been declining in Lake Sallie since 1981 (Table 13). This is a broad indicator that water quality is improving in Lake Sallie.

Table 13. Ratio of black:yellow bullheads. Based primarily on trap net data from the MnDNR fish survey records.

1949	18.5
1953	22.5
1968	1,012
1971	1,265
1972	3,437
1981*	13.5
1984	6.5
1989	3.8
1994	1.9

* first fish survey conducted after the sewage treatment discharge was diverted in 1976.

2.4. Estimating Lake Improvements Based On Phosphorus Reductions

Using a lake model spreadsheet, we can estimate Lake Sallie's phosphorus concentration under various nutrient loading conditions (Table 14).

Table 14. Predicted Lake Sallie phosphorus concentrations based on phosphorus loading to Lake Sallie.

Improvement	P load (kg) to Lake Sallie	Predicted P conc (ug/l) in Lake Sallie	Comments
1. Existing conditions with internal Lake Sallie loading (1995 estimate)	4,971	67 - 81	Internal load estimated at 3,535 kg.
2. Reduce Pelican River 50% (-600 kg)	4,371	63 - 72	Use 1995 load, reduce SC 3 and Muskrat Lake inputs.
3. Eliminate internal loading in Lake Sallie (1996 estimate)	2,334	40 - 44	Use 1996 loading data. Internal loading was not significant in 1996.
4. Eliminate internal loading reduce Pelican River 50%	1,734	30 - 37	Using 1996 loading minus 600 kg.

Of the three phosphorus reduction conditions, reduction of the internal phosphorus load is likely to have the greatest effect on Lake Sallie's phosphorus concentration. While watershed improvements aimed to control external phosphorus loading are important, the model predicts that phosphorus reductions from the Pelican River alone are not enough to reduce the in lake phosphorus concentration to the goal of 30 ppb.

Reducing the internal phosphorus loading in Lake Sallie is critical to reducing nuisance summer algae blooms.

The field data and model predictions suggest that the conditions in Lake Sallie aren't likely to improve without controlling the internal phosphorus load.

We will propose projects that will reduce watershed phosphorus loading to Lake Sallie which will hopefully prevent internal phosphorus release. We are predicting that by reducing the amount of phosphorus coming into Lake Sallie, especially spring phosphorus, that spring and early summer algae growth will be low. This should result in a low sediment oxygen demand in Lake Sallie in mid to late summer and possibly avert anoxic conditions and subsequent phosphorus release.

An alum treatment in Lake Sallie would be an option if other phosphorus reduction projects failed to reduce phosphorus loading to the extent it did not reduce internal loading. Alum (aluminum sulfate) is an aluminum salt which serves two purposes: removing phosphorus from the water column and controlling phosphorus release from the sediments. Alum is effective in controlling phosphorus release from the sediments because the aluminum ions form complexes with phosphorus in the sediments and these complexes are stable even under anoxic conditions, and thus the phosphorus is trapped in the sediments.

2.5. Conclusions

☐ Lake Sallie is recovering . . . but slowly, there are good and bad years.

☐ Years with internal loading cause nuisance algae conditions and years without internal loading may not be producing nuisance algae blooms.

☐ Weather (rain, temperature, wind) impact lake stratification and internal loading as well as Muskrat Lake inputs.

☐ We theorize that some of the phosphorus released from Lake Sallie sediments in mid-summer is from spring inputs and some of the internal P is old phosphorus.

☐ An important spring source of P is Lake St. Clair, and an important summer source of P is leaching from wetlands.

☐ An alum application in St. Clair would reduce high spring phosphorus loads into Lake Sallie.

☐ The summer leaching of phosphorus from wetlands will be tough to halt. However, because Ditch 14 flows are reduced in summer, there is a longer retention time in Muskrat Lake and time for the P to be taken up by the algae in Muskrat Lake.

☐ Muskrat Lake can be a significant phosphorus sink. It can also be a significant source. Steps should be taken to optimize conditions so it remains a sink. These include maintaining a robust plant community and possibly enhancing the gamefish community to enhance biomanipulation affects. Also, we want to keep Muskrat Lake from going anoxic to minimize internal loading. Phosphorus release from Muskrat Lake sediments will end up in Lake Sallie.

☐ Two other areas need to be maintained. Good water quality in Detroit Lake will benefit Lake Sallie and the direct drainage watershed around Lake Sallie needs ongoing protection.

3. Lake Sallie Implementation Plan

3.1. Implementation Plan Strategy

Sources of Phosphorus: The impacts from past sewage treatment effluent discharges in the watershed may still be impacting Lake Sallie, indirectly by way of Lake St. Clair and Ditch 14 wetlands. It appears that Lake St. Clair outputs excessive phosphorus in early spring. We suspect elevated phosphorus may be from internal loading occurring during ice-covered winter months. Part of this phosphorus load may derive from previous wastewater treatment effluent discharges into Lake St. Clair with subsequent deposition in the sediments. In summer, surface water in Ditch 14 appears to have elevated phosphorus concentrations. Our study in the summer of 1996 found elevated phosphorus concentrations in the wetland soil interstitial water (pore water). We have not determined if the source of elevated phosphorus is from groundwater with elevated phosphorus concentrations or if groundwater is receiving elevated phosphorus from wetland soils that have been loaded with phosphorus from previous wastewater treatment plant discharges. Since 1976, there has been a dramatic decrease in phosphorus in the wastewater discharged in the Lake Sallie watershed, however there may still be a considerable amount of phosphorus in the wetland soils. More work will be needed to address this.

The source of groundwate related phosphorus needs clarification.

Although water quality trends indicate Lake Sallie is improving (based on phosphorus, algae, and fish), it is still eutrophic. Recently, in years when internal phosphorus loading has occurred in Lake Sallie, nuisance algae blooms have occurred. In years when internal loading does not occur, Lake Sallie, for the most part has low level algae blooms and acceptable water transparency for a large part of the summer. If we could reduce internal loading in Lake Sallie, we may be able to achieve water quality goals, most of the time.

A sediment alum treatment in Lake Sallie would probably work, but we would like to use less costly alternatives to accomplish the same objective . . . which is to reduce internal loading in Lake Sallie.

Our question is how to reduce internal loading in Lake Sallie. A lake wide alum treatment would probably solve this, however, there is a risk of adverse impacts to the high quality fish community, the alum treatment is costly, and there is no guarantee it would work or if it did work, we don't know how long it would be effective.

Strategy: Our strategy is to reduce internal loading in Lake Sallie by reducing watershed phosphorus loading. It is likely that spring phosphorus loading produces diatom production which settles out of the water column in May. Other researchers have described how spring phosphorus inputs can end up recycling in summer Lazzaretti et al (1992), Nixidorf (1990), and Zhang and Prepas (1996). When this biomass decomposes it can produce two effects: first phosphorus is released as part of algae cell decomposition and secondly, there is an oxygen demand created as decomposition progresses. In years with high spring phosphorus inputs to Sallie, there may be a high enough oxygen demand to create anoxic conditions in the bottom water which in turn could promote significant phosphorus release from Lake Sallie sediments. One approach is to reduce wintertime Lake St. Claire phosphorus loading at its source, which is suspected to be the lake sediments, by using a whole-lake alum sediment treatment. We have a different strategy for reducing the impacts on Lake Sallie from Ditch 14 summer phosphorus loading. It would be difficult (but not impossible) to reduce the phosphorus loading at the source which is probably the Ditch 14 wetland soils. We propose to enhance biomanipulation effects in Muskrat Lake as a way of dampening the phosphorus load from Ditch 14 sources.

An ecosystem management approach represents a low cost and low intrusive alternative for improving Lake Sallie compared to a sediment alum treatment in Lake Sallie.

Summary: We are proposing an ecosystem management approach that stresses sound watershed clean water practices combined work in other watershed water bodies to improve water quality conditions in Lake Sallie. These approaches are lower in cost and environmental impacts compared to a Lake Sallie alum treatment ($400,000).

If our ecosystem projects were found to not produce improved water quality in Lake Sallie, we could then implement what we are calling, reserve projects, to reduce phosphorus concentrations and nuisance algae conditions in Lake Sallie.

Therefore, this is a phased lake improvement program. With low cost projects being implemented first, and if they don't work, several other projects could be considered.

3.2. Implementation Plan Project List

The Lake Sallie implementation program has four components: **1. Best Management Practices**, which will protect Detroit Lake and maintain a high quality water supply to Lake Sallie; **2. Special Watershed Projects**, which are designed to reduce internal phosphorus loading in Lake Sallie; **3. Ongoing Lake Projects** which are Lake Sallie maintenance projects; and **4. Reserve Projects**, which could be considered if other projects are not effective..

The recommended projects are listed in Table 15. The implementation projects are summarized in Table 16.

Table 15. Recommended watershed implementation projects for Lake Sallie

1. **Watershed best management practices and related measures**
   a. Detroit Lake storm water runoff treatment installation
   b. Septic system monitoring/upgrades/sewer conversions
   c. Shoreland zone management practices
   d. Improve feedlot and other agricultural practices
   e. Streambank protection and stabilization

2. **Special Watershed Projects**
   a. Alum treatment in Lake St. Clair
   b. Improve boat access on Muskrat (for easy access of the weed harvester) and harvest filamentous algae combined with cutting fish cruising lanes.
   c. Winter aerator, on standby, to prevent winterkill in Muskrat Lake, combined with stocking
   d. Wetland projects: checking phosphorus sources and methods for phosphorus reduction

3. **On-going Lake Sallie Projects**
   a. Aquatic plant harvesting in Lake Sallie
   b. Control of Flowering Rush
   c. Continued lake sampling for trend analysis especially for internal loading consideration

4. **Reserve Projects**
   a. In-lake alum treatment of Muskrat Lake
   b. Alum stream dosing on Ditch 14
   c. In-lake alum treatment of Lake Salllie

Table 16. Summary of implementation projects and how they will benefit Lake Sallie.

Projects	How They Benefit Water Quality
1. WATERSHED PRACTICES TO REDUCE PHOSPHORUS INPUTS TO LAKE SALLIE.	By protecting Detroit Lake, we maintain a low phosphorus concentration in the outflow and a low loading rate from Detroit Lake into Sallie. Currently, loading from Detroit Lake is acceptable. We also want to maintain ongoing BMP implementation in the direct drainage watershed of Lake Sallie.
2. SPECIAL WATERSHED PROJECTS **a. Alum treatment in Lake St. Clair**	Lake St. Claire outlet sampling results indicate high phosphorus loads in spring and lower loads in summer. We suspect that shallow Lake St. Claire loses water column oxygen over winter and experiences significant internal phosphorus loading. An alum treatment would reduce winter sediment phosphorus release and reduce spring phosphorus loading from Lake St. Clair.
b Improve boat access an Muskrat Lake and harvest filamentous algae and cut fish cruising lanes	We found that significant amount of phosphorus discharges from the wetland complex between Lake St. Clair and Muskrat Lake during the summer. We would like to reduce the phosphorus load before it gets to Lake Sallie. We have a two-fold strategy: 1) Use aquatic plants in Muskrat Lake to help remove phosphorus and 2) Use gamefish to control small fish, which produces a biomanipulation effect. To improve aquatic plants in Muskrat Lake, harvesting of filamentous algae would help. This allows more sunlight to get to the plants. To get a harvester into Muskrat, a better access would be needed. To allow gamefish good access to the small fish, cruising lanes could be cut into the weed beds in Muskrat Lake Custom harvesting would allow maximum fish effects while maintaining a good aquatic plant community.
c. Winter aerator, on standby, to prevent winterkill in Muskrat Lake, combined with fish stocking.	Over a long, cold winter, Muskrat Lake could be susceptible to winterkill, especially if the Pelican River freezes over. To maintain a robust predator fish population, a winter aeration unit should be available, if needed, to make sure there is not a catastrophic fish kill. Depending on angler fishing pressure and other factors, it may be necessary to supplementally stock Muskrat lake with gamefish. This is to maintain control over small fish. As long as an aerator is on reserve, it should be acceptable to "beef" up the gamefish through stocking.
d. Wetland projects: checking phosphorus sources and method for phosphorus reductions.	In 1996 we found strong evidence for significant phosphorus discharge from Ditch 14 wetland systems. Additional work is needed to find the source of the phosphorus. If phosphorus reduction from the wetland complex on Ditch 14 is necessary, an option may be groundwater aeration. A small-scale demonstration would help to determine the feasibility of a large-scale project.
3. ON-GOING LAKE SALLIE PROJECTS **a. Aquatic plant and filamentous algae harvesting**	Harvesting on Lake Sallie reduces nuisance conditions associated with rapidly growing plant communities. Although aquatic plants are desirable in lakes, harvesting facilitates plant management while sustaining aquatic plant community benefits.
b. Control of Flowering Rush	Aquatic plant harvesting should control the exotic flowering rush.
c. Continued lake sampling for trend analyses	We need to keep monitoring Lake Sallie to check the phosphorus status. Incoming phosphorus and internal release need to be characterized. If trends show that Lake Sallie is not improving based on the projects that have been implemented, then the reserve projects may be called for.

Projects	How They Benefit Water Quality
4. RESERVE PROJECTS **a In-lake alum treatment of Muskrat Lake**	Another way to remove phosphorus associated with Ditch 14 may be to do a one-time alum trea in Muskrat Lake. Research has shown that a sediment alum treatment may remove water colum phosphorus as well as inactivating sediment phosphorus. Therefore, as Ditch 14 water flows th Muskrat Lake on the way to Lake Sallie, phosphorus could be removed in Muskrat Lake.
b. Alum dosing on Ditch 14	Previous research has shown that alum injection into water or groundwater will reduce orthophosphorus concentrations. If summertime phosphorus from Ditch 14 is not being adequat handled in Muskrat Lake, and if aeration is not feasible, then alum dosing could be considered. the present time, drinking water standards for aluminum apply and it would be fairly expensive t install an alum dosing system.
c. In-lake alum treatment of Lake Sallie	An option for improving Lake Sallie by way of reducing internal loading is a whole-lake sedimen alum treatment. There are enough examples to indicate it would have a high probability of worki However, there is a possibility of adversely impacting the benthic invertebrate community which, ultimately, could effect the high quality walleye population. Also a whole-lake alum treatment w be expensive. This project is a reserve project and would be considered only after earlier options were installed and did not work.

3.3. Implementation Plan Details

1. Watershed best management practices and related measures

This category contains five projects. The Pelican River Watershed District has already started to implement a number of these projects.

While underlying water quality problems in Lake Sallie are not principally the results of current riparian or upstream non-point sources, these sources must be controlled in order to satisfactorily solve it's problems.

The District is confident that much of this nutrient enrichment can be controlled by application of "Best Management Practices" and related activities in watershed areas upstream from Lake Sallie. The District will give its fullest attention to promoting the following measures.

1a. Detroit Lake storm water runoff treatment

Stormwater project details are available in a 1995 report prepared for the District by Larson-Peterson and Associates.

It is believed that a substantial part of the nutrient load which reaches Detroit Lake is introduced in the urban areas which drain to the Pelican River. Similarly, storm drainage to County Ditch #14 which leads to Lake St. Clair and eventually to the Pelican River is believed to contribute to residual nutrients found in Lake St. Clair and nearby wetlands.

As a high priority, properly designed storm treatment systems (wet sedimentation basins or the equivalent) should be installed to intercept each storm water outfall. No storm water should be directed to the Pelican River or County Ditch #14 without such treatment. There are now at least 13 outfalls requiring enhanced treatment or further study. In several cases, effective treatment can be accomplished by converting existing dry sedimentation basins into wet basins.

There are seven other dry sedimentation or slow-release basins located in the storm collector system of the City of Detroit Lakes. These should be converted to wet-type detention basins in order to obtain maximum removal of nutrients prior to discharge into the Pelican River or its tributaries. Such conversions are known to produce phosphorus reduction from as little as 15% to as much as 95%, depending upon catchment areas, structure design and other factors.

At least three major storm-water collecting systems bring untreated runoff from approximately 425 hectares of urban land to the northeast arm of Ditch #14 or into wetlands which drain to the ditch. It is believed that, taken together, these carry about 300 kilograms of phosphorus. Another system drains to Ditch #14 through a sediment detention pond. Additional data are required to precisely ascertain the loadings to wetlands, to Ditch #14, and thence to Lake St. Clair; information is also required to ascertain the conditions under which these nutrients are subsequently released to the Pelican River above Muskrat Lake.

In considering these measures, it is noteworthy that the Watershed District enjoys the full cooperation and support of the City of Detroit Lakes. Indeed, the City has specified storm water management as atop priority goal in its current ten year plan.

Costs: These are ongoing projects. It is estimated that the District will expend at least $170,000 over the next six years in storm water management related activities. The details of projects and costs were prepared by Larson-Peterson and Associates in an engineering report in 1995.

1b. Septic system monitoring, upgrades, and sewer conversions
It is generally accepted that septic upgrades should be emphasized throughout the District, but particularly in those areas adjacent to District lakes and streams. An initiative to review all septic systems is part of the Becker County's Comprehensive Water Plan, and is underway. Experience in this program has shown that about 20 percent of riparian septic systems do not comply with existing standards (Minnesota Rule Chapter 7080). The county requires upgrade of deficient systems, and monitors compliance.

It is widely believed that central waste-water treatment systems must eventually replace on-site sewage disposal, and that such conversions will reduce nutrient loads in District Lakes. The District will continue its encouragement of development of centralized systems, such as the one that is currently being constructed around the south and east shores of Detroit Lakes. Based upon widely-held perceptions of the dramatic reduction of nuisance aquatic vegetation associated with previous construction of sewers around north and west shores of Detroit Lakes, it is expected that water quality benefits will be obtained by the present project.

Costs: In-kind costs are expected to be a minimum of **$8,000** by the end of this six year project period. Costs for centralized sewer hook-ups are unknown at this time.

1c. Shoreland zone management practices
The Watershed District has promoted that strict enforcement of shoreland protection regulations adopted in 1992 by Becker County and the City of Detroit Lakes. Vigorous enforcement of provisions of the Wetland Conservation Act (1991) also is encouraged. The District monitors building and other permits, and requires its own permits for certain land development activities within its boundaries. Special attention is given to ensuring that best management practices accompany construction activities in shoreland areas (and upstream subwatershed areas too).

Such measures will not result in water quality enhancement, but they are intended to avoid further deterioration in water quality as a result of inappropriate near-shore and stream-side development activities.

The District will attempt to initiate a joint powers agreement or some similar instrument to ensure that proposed development projects are fully considered int he context of best management plans by all interested local parties, including township, county and city.

The City of Detroit Lakes prohibits the sale and use of fertilizer containing more than 1% phosphorus (by weight). Lake View Township, which includes the non-annexed areas near Detroit Lakes as well as the whole of the Basin, has a zero phosphorus requirement. It is generally thought that education is the key to a successful results from these ordinances. The Watershed District has begun a campaign to ensure that all residents and merchants are aware of the provisions of the ordinances. It is believed that reductions in fertilizer phosphorus will reduce phosphorus entering groundwater in and near the District's lakes and streams.

Costs: At this point costs are associated with enforcing ordinances and making residents aware of the existing ordinances and regulations. We estimate an annual in-kind cost of $1,666 for a six year total of **$10,000**.

1d. Improve feedlot and other agricultural practices
Working with Soil and Water Conservation District personnel and the USDA, as well as representatives of the Minnesota Pollution Control Agency (MPCA), and the Minnesota Department of Natural Resources (DNR), the District will work to encourage landowners to continue to upgrade their cropping and livestock practices. Most land owners are aware of the consequences of poor stewardship. Indeed, it is believed that some of the barriers to improving management in the subwatershed in which active agriculture is present can be traced to institutional problems.

With a view to speeding adoption of "best management practices", a prototype for coordinating mult-jurisdictional land management responsibilities in Becker County is currently being tested with MPCA as the lead agency. Special attention will be given to livestock operations and cropping areas near tributaries within the district.

Here too, strict enforcement of wetland regulations will be encouraged as it is recognized that active, healthy wetland can be beneficial in preventing nutrients and sediments fro entering streams and lakes.

Costs: At a minimum we anticipate an annual cost of $10,000 for in-kind assistance and landowner costs for installing practices. A six year cost is conservatively estimated at **$60,000**.

1e. Streambank protection and stabilization
A full inventory of streambank conditions will be compiled for the entire length to the Pelican River and its tributaries; streambank buffer zones will be planned; sites of bank erosion will be identified, and remedial measures will be undertaken. Of special interest here is the Campbell Creek area where gradients are high, and high runoff events have been accompanied by very high sediment and nutrient loads. Any land utilization practices that seem incompatible with the highest standards of stream protection will be targeted for remedial actions.

In addition, the District will oversee management of ditches within the watershed in 1997.

Costs: Streambank erosion central and ditch maintenance is conservatively estimated at $2,000 per year, for a six year total of **$12,000**.

2. Special Watershed Projects

In addition to conventional watershed projects, we have prepared four other watershed projects that are custom designed for addressing excessive phosphorus inputs from watershed sources.

2a. Alum treatment in Lake St. Clair

Lake St. Clair outlet sampling results indicate high phosphorus loads in spring and lower phosphorus loads in summer. Based on previous inflow sampling, stormwater does not appear to the a significant phosphorus source to Lake St. Clair. Phosphorus concentrations were generally less than 40 ppb and often flow was barely detectable. It appears that the most important phosphorus source in the Lake St. Clair system is from the lake sediments. We suspect that shallow Lake St. Clair loses water column oxygen over winter and experiences significant internal phosphorus loading. An alum treatment would reduce winter sediment phosphorus release and reduce spring phosphorus loading from Lake St. Clair.

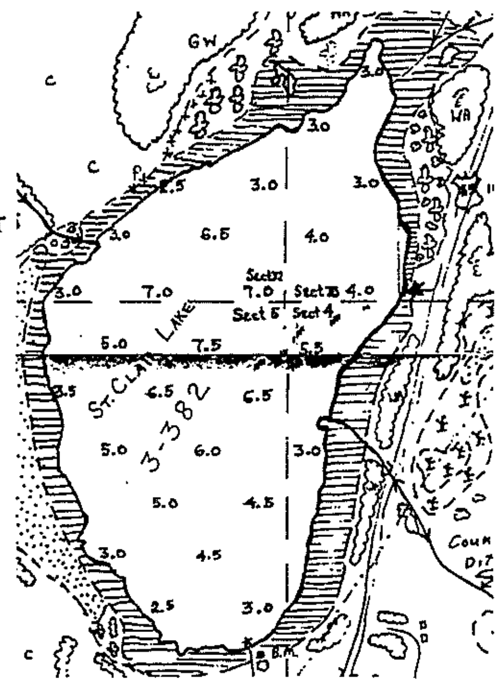
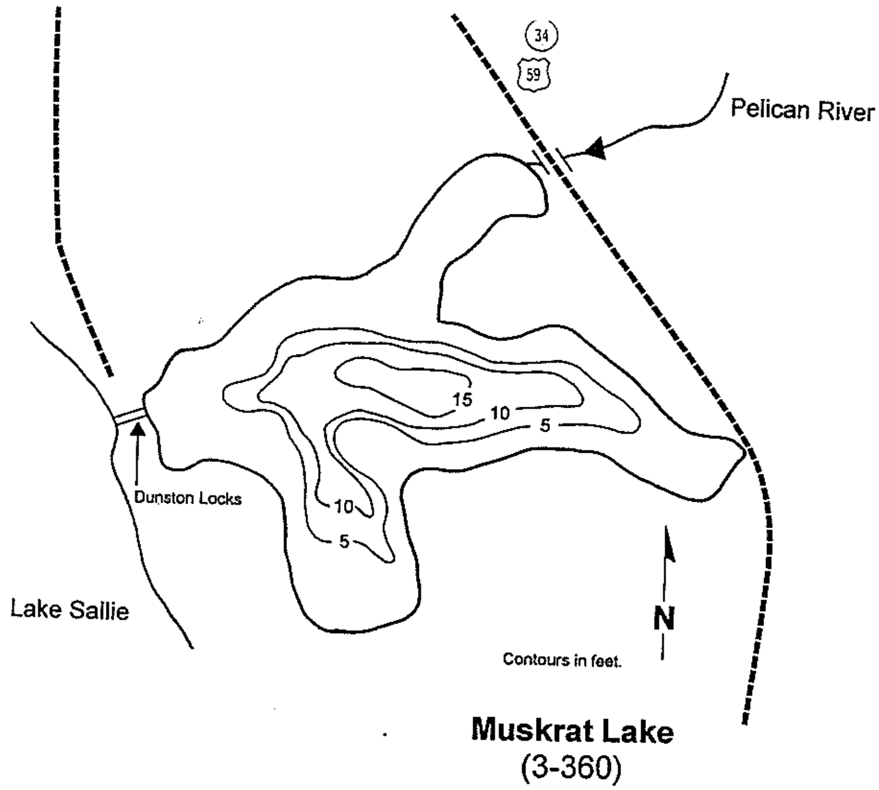


Figure 21. The Lake St. Clair basin is relatively shallow. Lake access for an alum treatment is on the east side. The lake is about 140 acres in size and about 70 acres would be treated.

It appears that lush plant growth (usually coontail) occurs in summer, and that water quality is fair (seven foot secchi). We propose to treat at least 100 acres of the 140 acre lake basin, or roughly 70% of the basin area. A lake survey needs to be completed to recheck water depths which would dictate what kind of a barge could be brought in to do an alum treatment. Up to 120 acres could be treated if conditions allow.

Costs: The going rate of alum application per acre is $400 per acre at a dose rate of 400 gallons (as liquid alum). A minimum cost would be around **$40,000**. Based on a lake survey and jar tests, a higher dose could be considered. Alum costs are approximately $1.00 per gallon.



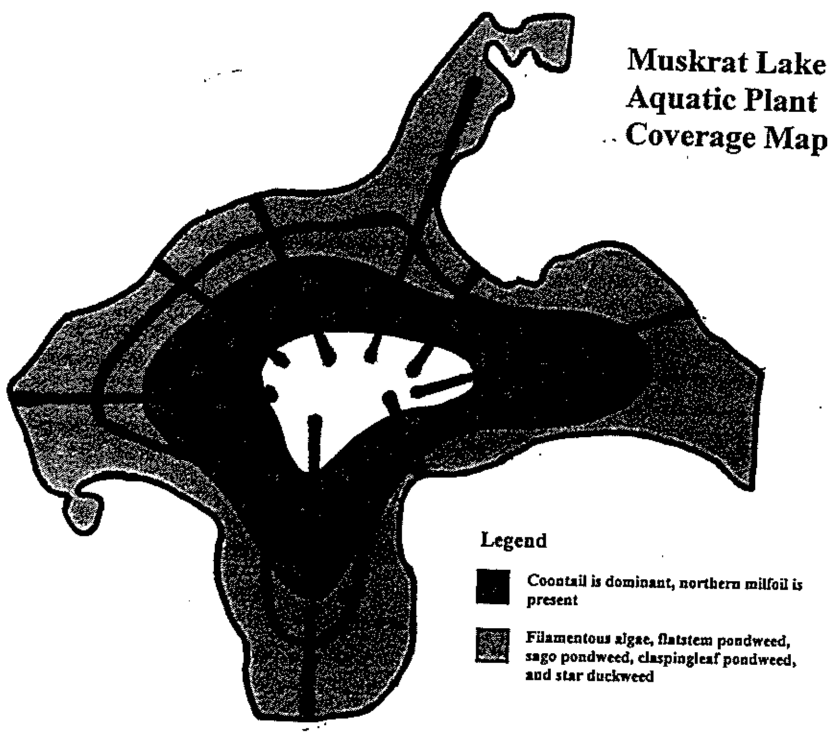


Figure 22. [top] A bathymetric map for Muskrat Lake and an aquatic plant coverage map. [bottom] Transects of potential harvested cruising lanes are shown on the bottom map.

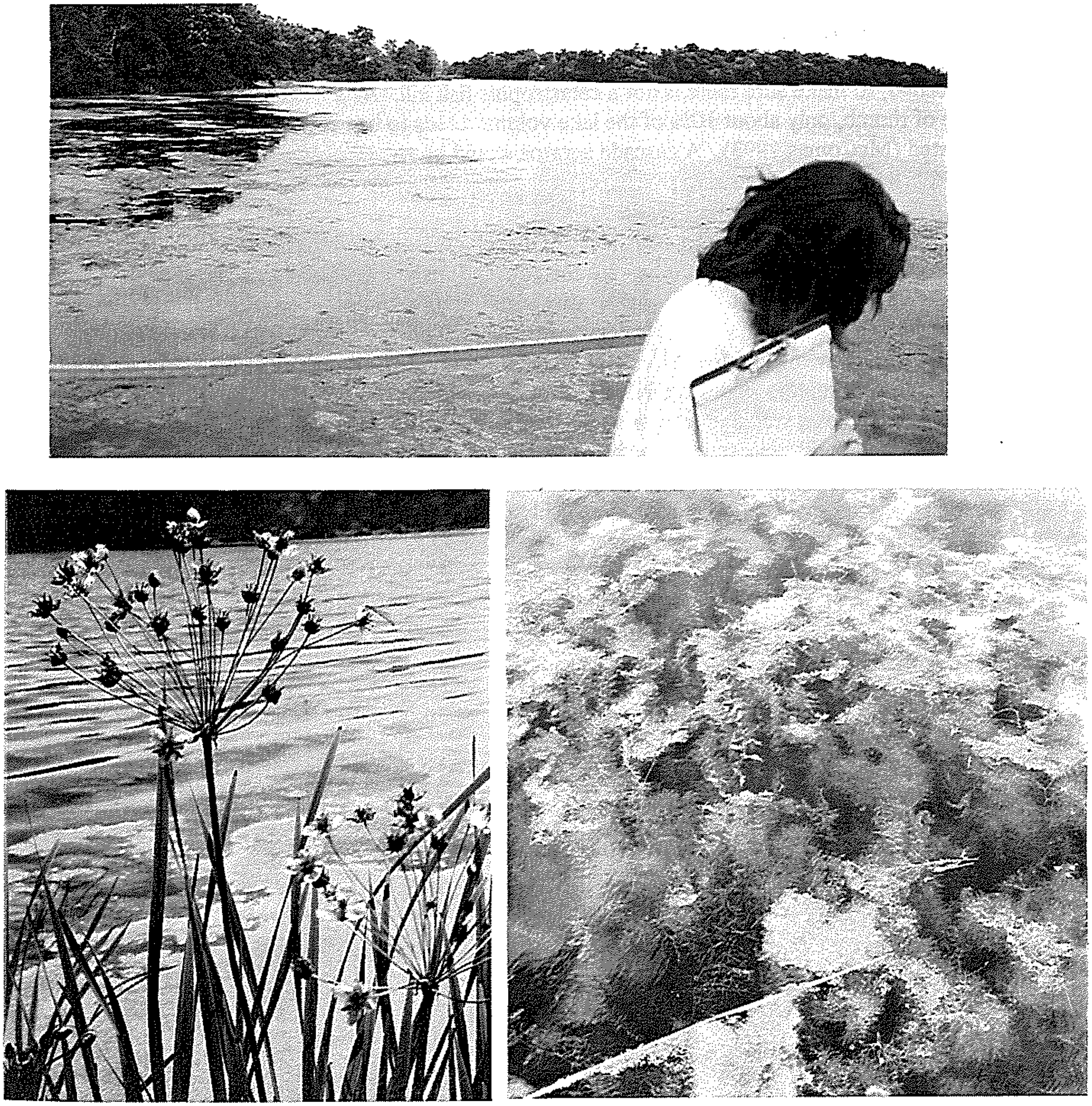


Figure 23. Existing aquatic plant conditions in Muskrat Lake. [top] Aquatic plants come to the surface in much of Muskrat Lake. [bottom left] Flowering rush is present in the lake. [bottom right] Northern milfoil and sago pondweed are important species in Muskrat Lake. Filamentous algae sometimes seems to rest on top of the submerged plants.

2c. Winter aerator, on standby, to prevent winterkill in Muskrat Lake, combined with fish stocking.
Because Muskrat Lake (Figure 24) is relatively shallow, over a long, cold winter, Muskrat Lake could be susceptible to winterkill, especially if the Pelican River freezes over. To maintain a robust predator fish population, a winter aeration unit should be available, if needed, to make sure there is not a catastrophic fish kill. As a rule of thumb, only about 10% of the lake volume needs to be aerated (McComas 1993). A cascade aerator would be an appropriate choice (Figure 25).

Because we are attempting to exert top-down impacts from piscivorous fish, we need to go beyond the conventional approach of relying on recruitment from other nearby water bodies, in this case Detroit Lake. It may be necessary to supplementally stock Muskrat Lake with gamefish. This is to maintain control over small fish. We would work with MnDNR fisheries personnel to determine the best stocking program. As long as an aerator is on reserve, it should be acceptable to "beef" up the gamefish through stocking. Although fish can migrate to and from Detroit Lake, supplementally stocking of adult fish, possibly bass, may enhance small fish control.

Costs: A cascade aerator costs approximately $14,000. Hook-up costs and O & M over six years could cost another $10,000. Supplemental fish stocking as well as fish surveys would cost another $9,000. Total project cost is **$33,000**.

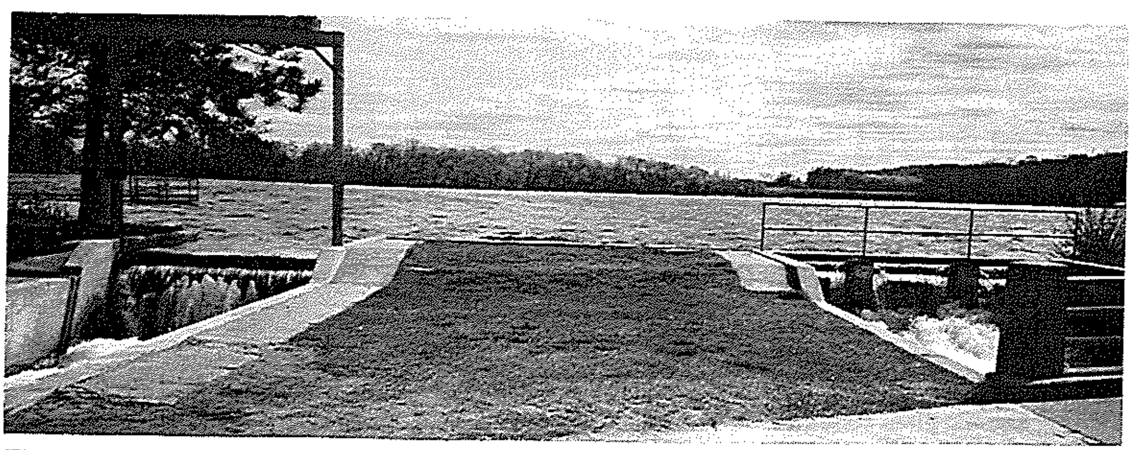


Figure 24. A cascade aerator could be backed into position along a shoreline area on Muskrat Lake if needed during a potential winterkill situation. This is a view of Muskrat Lake. It's about 67 acres with a maximum depth of 18 feet.

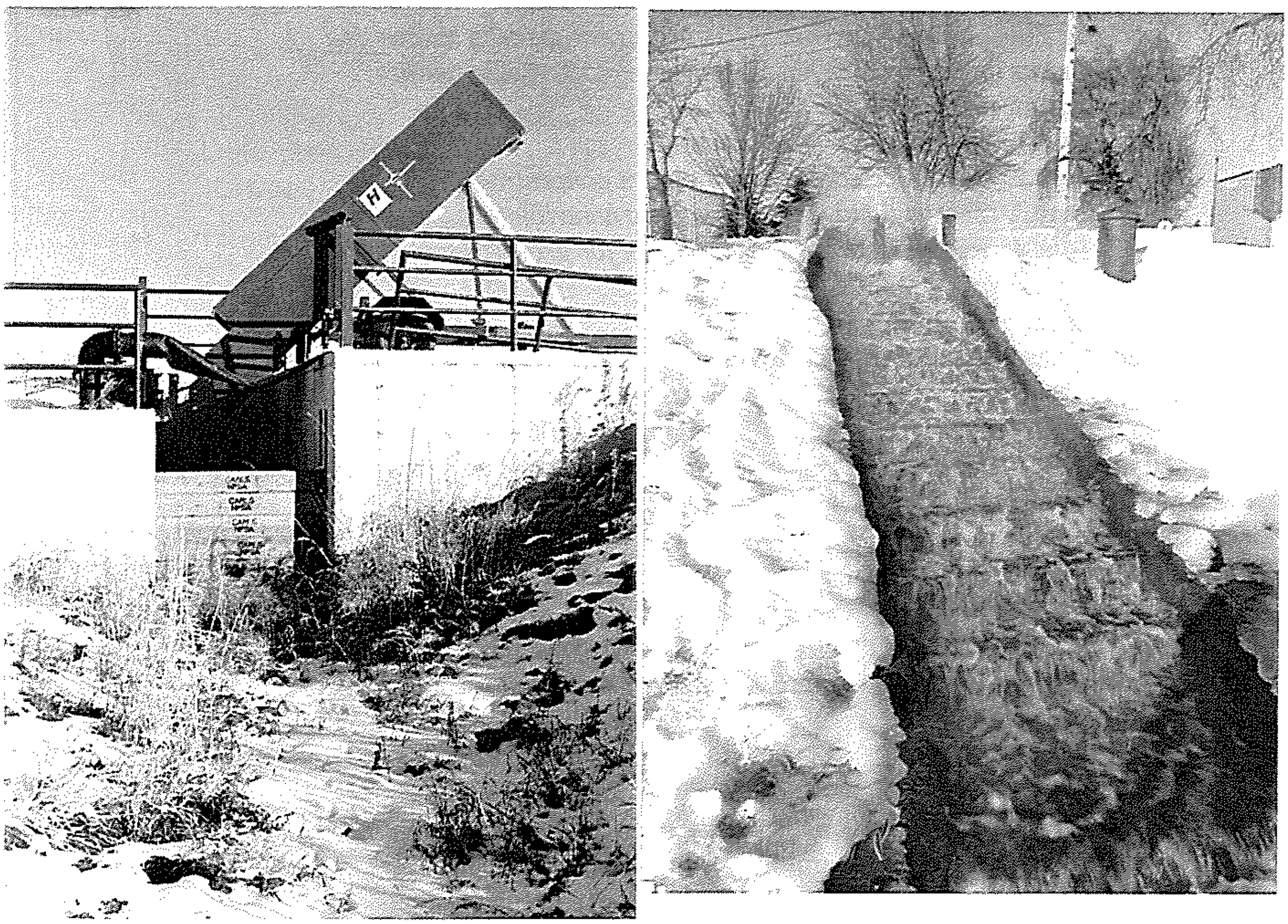


Figure 25. An example of a cascade aerator. The idea is to withdrawal water from the lake and pump it to the top of a cascade. As the water tumbles down the cascade, it becomes aerated and returns to the lake. A relatively small area of the lake is opened up.

2d. Wetland projects: checking phosphorus sources and studying a method for phosphorus reduction.
In 1996 we found strong evidence for significant phosphorus discharge from Ditch 14 wetland systems (Figure 26). Additional work is needed to find the source of the phosphorus. If phosphorus reduction from the wetland complex on Ditch 14 is necessary, an option may be groundwater aeration. A small-scale demonstration would help to determine the feasibility of a large-scale project.

Checking Phosphorus Sources: To further investigate the source of phosphorus in groundwater that is impacting Lake Sallie, we are proposing four tasks.

Task 1. Review existing information.
Task 2. Test selected wells for nutrient concentrations.
Task 3. Test wetland soils for nutrient contributions.
Task 4. Resample areas in Lake Sallie for groundwater inputs.

Details for each task are given below:
Task 1) Review existing information: An extensive data base has been generated over the last 40 years and the first task is to review and interpret the data base. This will allow us to determine the best sites to sample to further refine the groundwater phosphorus question. We will review documents from the U.S. Geological Survey, MPCA, and the Pelican River Watershed District.

Task 2) Test selected wells for nutrient concentrations: Based on review of the existing literature, we will confer with the MPCA and the District to select a number of wells for testing. We will select between ten to twenty wells for sampling and then sample them three times over the course of the spring and summer. We will analyze samples for orthophosphorus, iron, and chlorides. We will also conduct some stable isotope testing. We will use input from Joe Magner, MPCA, to help select the proper isotope testing methodology. We are keeping the sampling program flexible at this time, until we have a chance to fully review the data base.

Task 3) Test wetland soils for nutrient contributions to groundwater: Startling sample results collected this summer (by R. Nustad, D. Hecock, and S. McComas, Appendix B) for shallow access points in wetlands, showed high phosphorus and high iron concentrations. A question that we did not answer is where this phosphorus came from . . . does it reflect high groundwater phosphorus concentrations or is phosphorus leaching from the wetland soils, or is it a combination of the two. This is a critical set

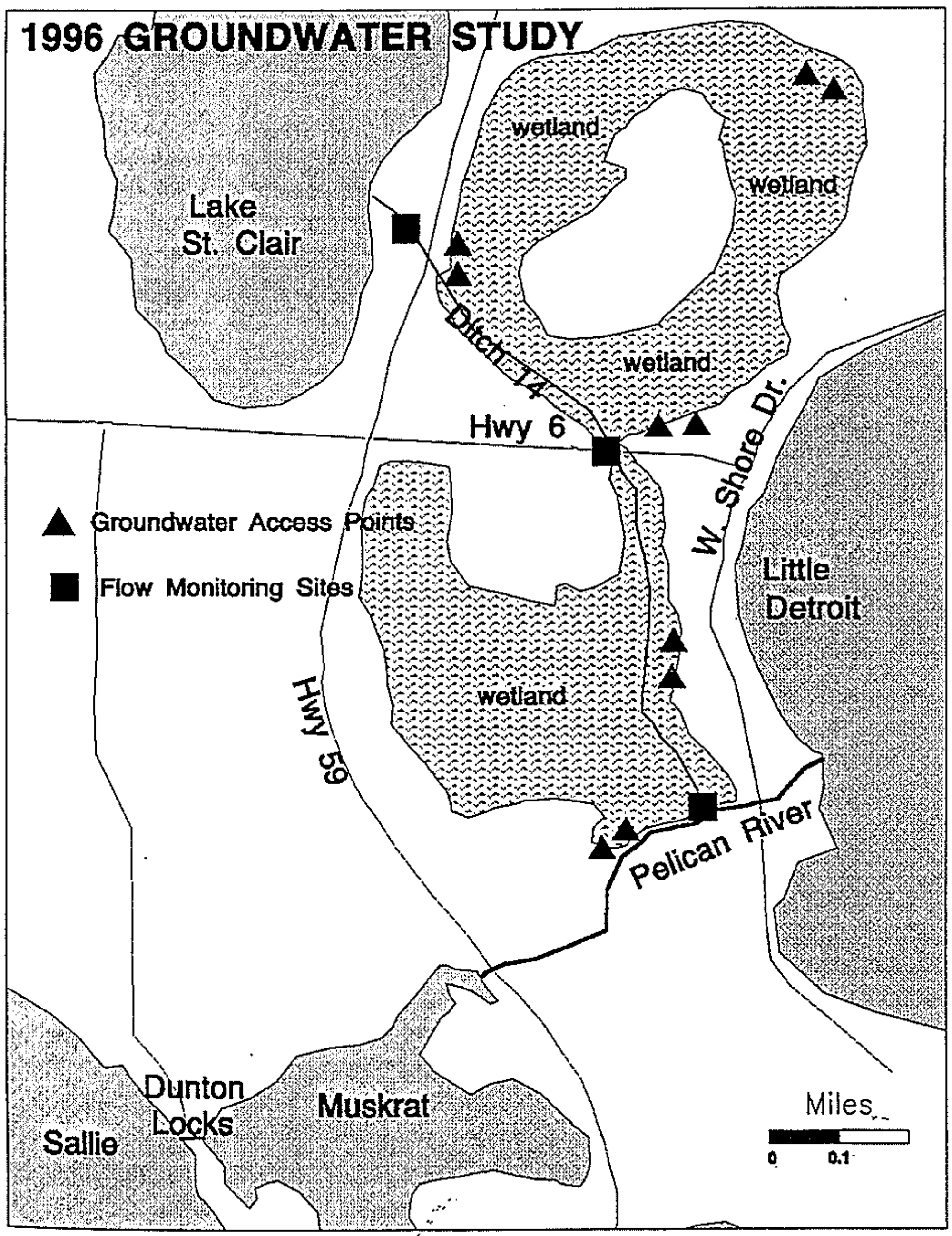


Figure 26. Wetland study area for the 1996 study.

of questions to address, because it will probably influence rehabilitation recommendations. Therefore we are proposing a set of laboratory leaching experiments to help answer these questions.

Three sites in the Watershed will be selected based on data review. At each site we will sample three locations with replicate peat samples taken at each location. For example, we will probably select one or two sites in the wetland complex that feeds Ditch 14. When a general site is selected, we will take peat samples from three locations on a transect toward Ditch 14. We will look to see if there is evidence for a nutrient gradient toward Ditch 14. At each location, peat samples will be collected. A subsample of the peat will be sent directly to the lab for nutrient analysis, while the rest of the peat will be placed in a 6-inch diameter PVC column. A total of 18 columns will be prepared. The peat in the columns will be rinsed with distilled water and then new distilled water will be added. The peat column will then sit for 90 days. Five samples will be withdrawn over the 90 day period and tested for orthophosphorus. On two occasions water samples will be tested for iron as well.

Results should tell us if wetland soils leach significant amounts of phosphorus indicating whether they are a significant phosphorus source or not. We will also compare column results with what we found in the field in the summer of 1996.

Task 4) Lake surveys for characterizing groundwater inputs to Long, Fox, Monson and Sallie: We propose to check groundwater inflows to Long, Fox, Monson, and Sallie using four different methods. The first is to use existing data on groundwater flow and hydraulic conductivities in the area to estimate flows. The second approach is to use an aerial survey in early spring, to be flown by A.W. Research (offices in Brainerd and Detroit Lakes). They will look at open water along shorelines in late winter that is usually indicative of groundwater inputs. The third technique is to conduct a shoreline survey from a boat using a conductivity meter and a sensitive thermometer. Changes in conductivity and temperature are indicative of groundwater inflows. I have been successfully using this approach for fourteen years. The fourth approach is to insert minipiezometers along the shoreline and look for differences in hydraulic head. This also gives an indication of areas of groundwater inflow and outflow.

Based on the results of these four types of surveys we should get a good idea of the areas and magnitude of groundwater inflow.

We will also be sampling some wells in these areas for phosphorus concentrations. Well locations will be determined in Task 2. These combined data should allow us to estimate phosphorus loading from groundwater.

Groundwater aeration demonstration: Based on results from the groundwater study we may find it is possible to reduce phosphorus discharge from the wetland by injecting oxygen to the subsurface water. If we can oxygenate the water, we may be able to get iron to precipitate which would remove phosphorus as well. Subsurface aeration is getting to be a proven technology. It is commonly used for remediation at hazardous waste sites to oxidize organic wastes. Although the basic methodology is available it has not been used for phosphorus inactivation in wetlands. Our approach is to use aeration to reprecipitate iron in wetland pore water along stretches of Ditch 14 in order to tie up phosphorus.

Groundwater aeration would be an ecologically friendly alternative compared to alum dosing of the wetland or in Ditch 14.

We will conduct several experiments. First we will look at the biochemical oxygen demand in the sediments over the course of the summer. This would give an indication of the magnitude of oxygen necessary to aerate the groundwater. We will also use column tests (triplicate sets) where we will inject compressed air into the peat and check for dissolved phosphorus and iron reductions in the pore water.

The last step will be to conduct a pilot demonstration in the field. We will isolate a one to two meter length of wetland near Ditch 14. We will install a manifold of PVC pipe and use an air compressor to inject air into the subsurface. We will sample the pore water prior to injection and then continue monitoring for several days to track changes in nutrient and iron chemistry. The objective is to determine if this approach is a feasible alternative for reducing phosphorus discharge from the wetland to Ditch 14.

Costs: The total cost for the wetland projects is **$33,000**. The first part of this project is to characterize phosphorus sources with an estimated cost of **$22,000**. The second part of this project, the groundwater aeration demonstration, has an estimated cost of **$11,000**.

3. On-Going Lake Sallie Projects

The Pelican River Watershed District has been activity managing lake and watershed projects for a number of years. These activities would continue through the duration of the Phase II implementation period. Three project areas that are ongoing include: plant harvesting, flowering rush control, and trend monitoring.

3a. Aquatic plant and filamentous algae harvesting

Harvesting on Lake Sallie reduces nuisance conditions associated with rapidly growing plant communities. Although aquatic plants are desirable in lakes, harvesting facilitates plant management while sustaining aquatic plant community benefits.

The PRWD has a well organized aquatic plant management program and uses harvesters during the summer for Lake Sallie weed control (Figure 27). These efforts will continue through the implementation program.

Costs: The estimated cost of harvesting over a six year period is approximately **$60,000**.

Figure 27. [top] The PRWD's harvester working in Lake Sallie. [bottom] The aquatic plant community fluctuates in biomass production and in dominant species from year to year. Northern watermilfoil was an important species in 1996, but overall biomass was down compared to long term averages.

3b. Control of Flowering Rush
Aquatic plant harvesting should control the exotic flowering rush. The PRWD has been working to control the spread and reduce its nuisance level for several years. It is found in both Muskrat and Sallie Lakes. Repeated cutting in the same season seems to exert good control over nuisance stands of flowering rush (McComas 1994).

Costs: Flowering rush control is handled along with other aquatic plant harvesting work. It is estimated that about $10,000 per year is spent in labor and equipment by the PRWD, for a cost over the six year project period of $60,000.

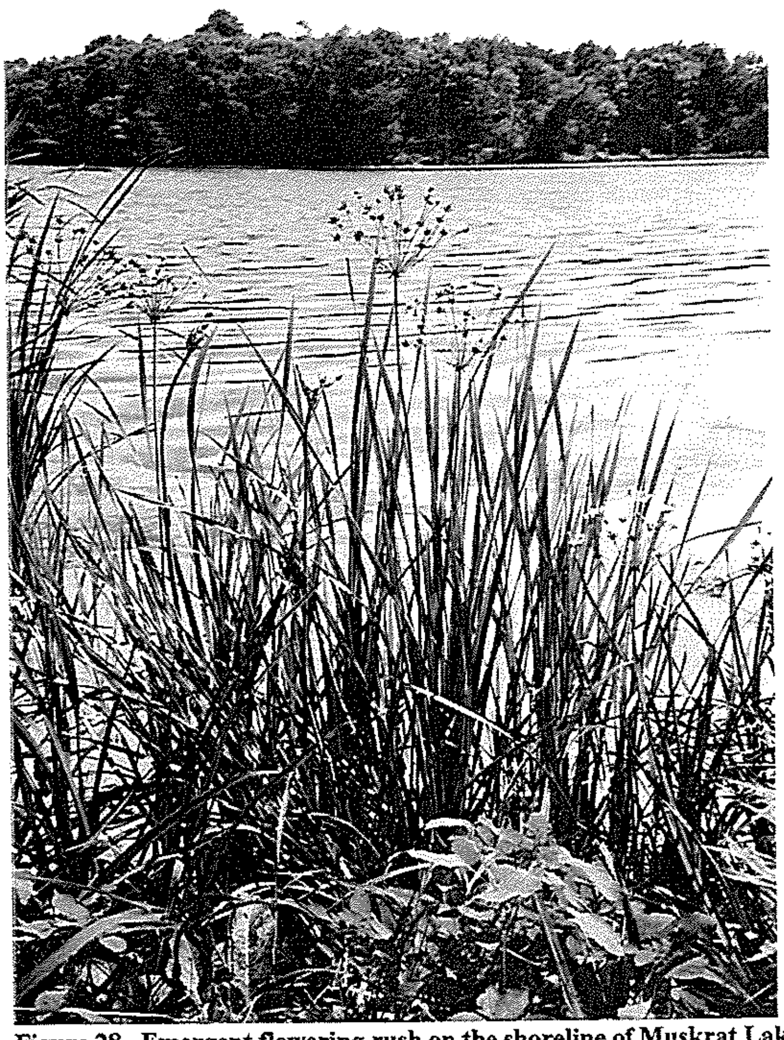


Figure 28. Emergent flowering rush on the shoreline of Muskrat Lake.

3c. Continued lake sampling for trend analyses

We need to keep monitoring Lake Sallie to track the lake phosphorus status. Both top and bottom water phosphorus concentrations need to be closely observed. This coupled with dissolved oxygen and temperature profiles will give insight to internal release dynamics. Another parameter we will measure is in-situ redox potential of lake sediments. Knowing the reducing potential of lake sediments will help us understand the timing and possibly the magnitude of an internal release episode. Also another parameter to monitor once or twice during the summer will be water column BOD and SOD (sediment oxygen demand).

If trends show that Lake Sallie is not improving based on the projects that have been implemented, then the "reserve" projects may be called for.

Costs: These tests are beyond the routine monitoring the PRWD is conducting. We estimate a six year program cost of **$18,000**.

Figure 29. Ongoing stream, ditch, and lake monitoring will allow us to check the effectiveness of implementation projects.

4. Reserve Projects

The implementation plan for improving Lake Sallie is sequenced to start with low cost, low intensity projects in an attempt to reduce the magnitude of internal release in Lake Sallie and thus reduce the occurrence of nuisance algae blooms.

If projects in Lake St. Clair and in Muskrat Lake are found to not be effective at getting critical nutrient reduction, then we have three additional reserve projects that could be implemented to reduce phosphorus concentrations in Lake Sallie. Sample results from Lake Sallie will be used to gage progress.

4a. In-lake alum treatment of Muskrat Lake

If biomanipulation influences are not strong enough to dampen or reduce phosphorus loads associated with Ditch 14 discharge into Muskrat Lake, supplemental projects may be implemented. Another way to remove phosphorus associated with Ditch 14 discharges may be to do a one-time alum treatment in Muskrat Lake (Figures 30 and 31). Research has shown that a sediment alum treatment may remove water column phosphorus as well as inactivating sediment phosphorus (McComas 1995). Therefore, the objective of an alum treatment in Muskrat Lake is two fold: as Ditch 14 water flows through Muskrat Lake on the way to Lake Sallie, phosphorus could be removed in Muskrat Lake. In addition, the alum treatment could reduce phosphorus release from lake sediments if the water column was to go anoxic over winter or in late summer.

Costs: Muskrat Lake is about 65 acres in size and we would apply alum to nearly the entire surface. Using an application rate of about 400 gallons of liquid alum/acre would cost roughly $400 per acre for a total cost of **$26,000**.

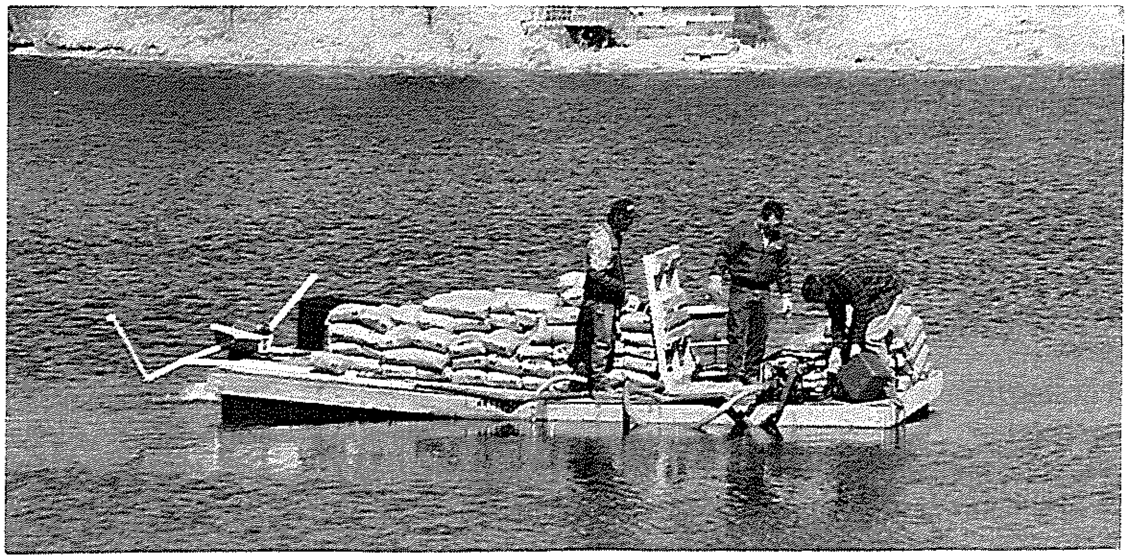


Figure 30. Here is an alum barge that is used for applying dry alum. Dry alum is applied for small projects and liquid alum is used for bigger projects.

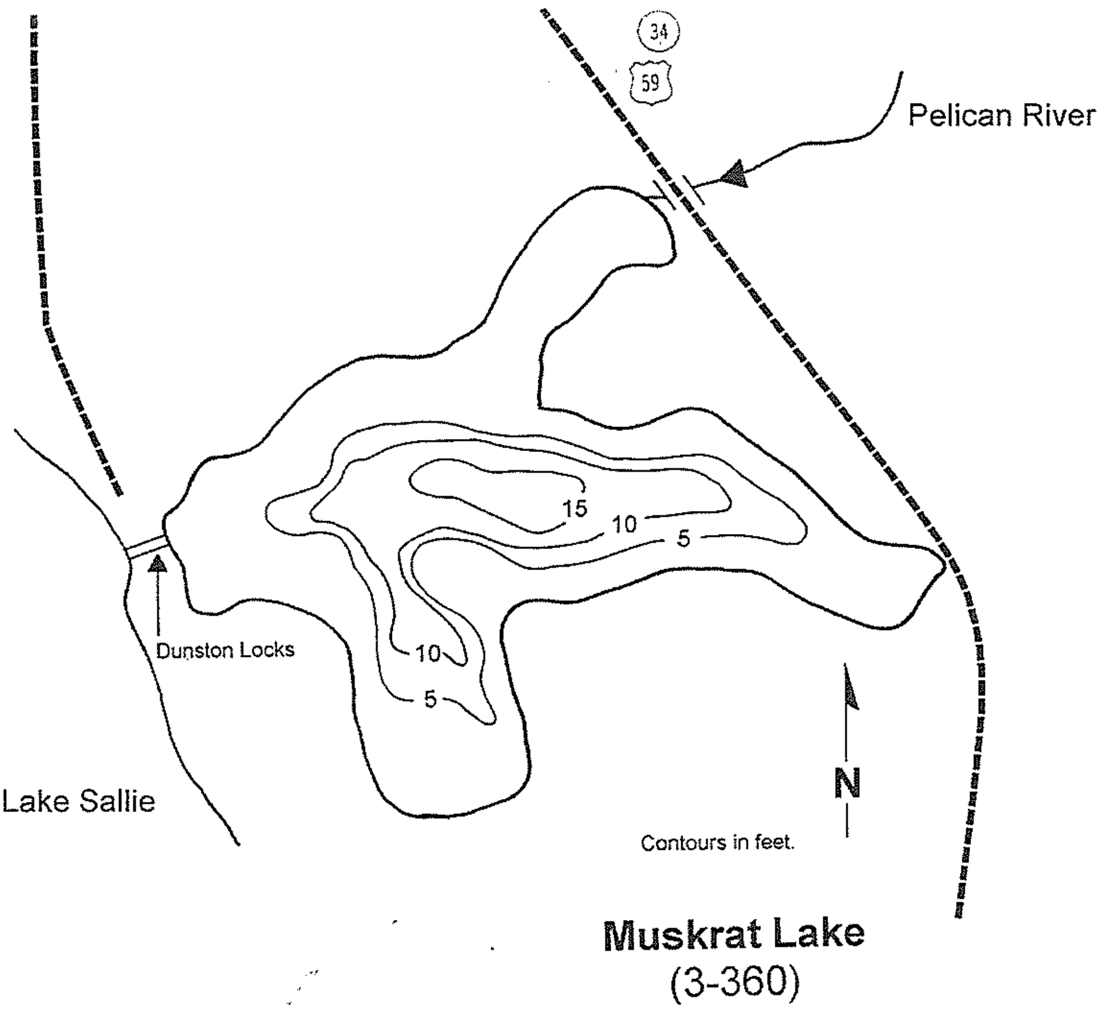


Figure 31. Contour map for Muskrat Lake. An alum treatment would blanket most of the bottom area with an aluminum hydroxide floc. Even though Muskrat Lake is shallow, other work has shown that bottom alum coverage stays in place (McComas 1995).

4b. Alum dosing in Ditch 14

Previous research has shown that alum injection or alum dosing into streams, stormwater, or groundwater can reduce orthophosphorus concentrations. If summertime phosphorus from Ditch 14 is not being adequately reduced through biomanipulation influences and if our first reserve project a Muskrat Lake alum treatment, does not reduce nutrient concentrations, then the next reserve project could be called upon. We would consider either a groundwater aeration or an alum dosing project as a way to reduce phosphorus loads in Ditch 14 discharges. At the present time, drinking water standards for aluminum concentrations apply to public waters. Therefore we would have to build a constructed wetland or a sedimentation basin to capture the aluminum floc before it went into the Pelican River, a protected public water. It would be fairly expensive to install an alum dosing system.

However, if an in-ditch alum capture system could be installed to remove alum and meet standards the project would be more economical.

The technology is available to implement effective stream dosing projects. Rules and regulations are in the process of being formulated, making the installation of this alternative uncertain at this time.

If alum dosing was to be considered a likely site would be at either the Ditch crossing at Hwy 59 or Hwy 6 (Figure 32). We would be looking at inactivating approximately 800 pounds of phosphorus per year. This is roughly 50 to 70% of the phosphorus loading discharged by Ditch 14. In an average year a percentage of the alum floc would settle in the ditch bottom and we would use a subsurface trap near the mouth of Ditch 14 to capture a significant component of the remaining floc.

We would use a 10:1 ratio aluminum to phosphorus for phosphorus removal. To remove 800 pounds of phosphorus would require 8,000 pounds of aluminum. The liquid alum requirement would be approximately 17,000 gallons of alum per year (liquid alum weighs 11 pounds/gallon and is 4.4% as aluminum).

Costs: Annual costs for alum would be approximately $15,000. We anticipate dosing for a minimum of three years. The capital costs for installation of tanks (2), piping, and metering is approximately $50,000. The total cost for this project is **$100,000**.

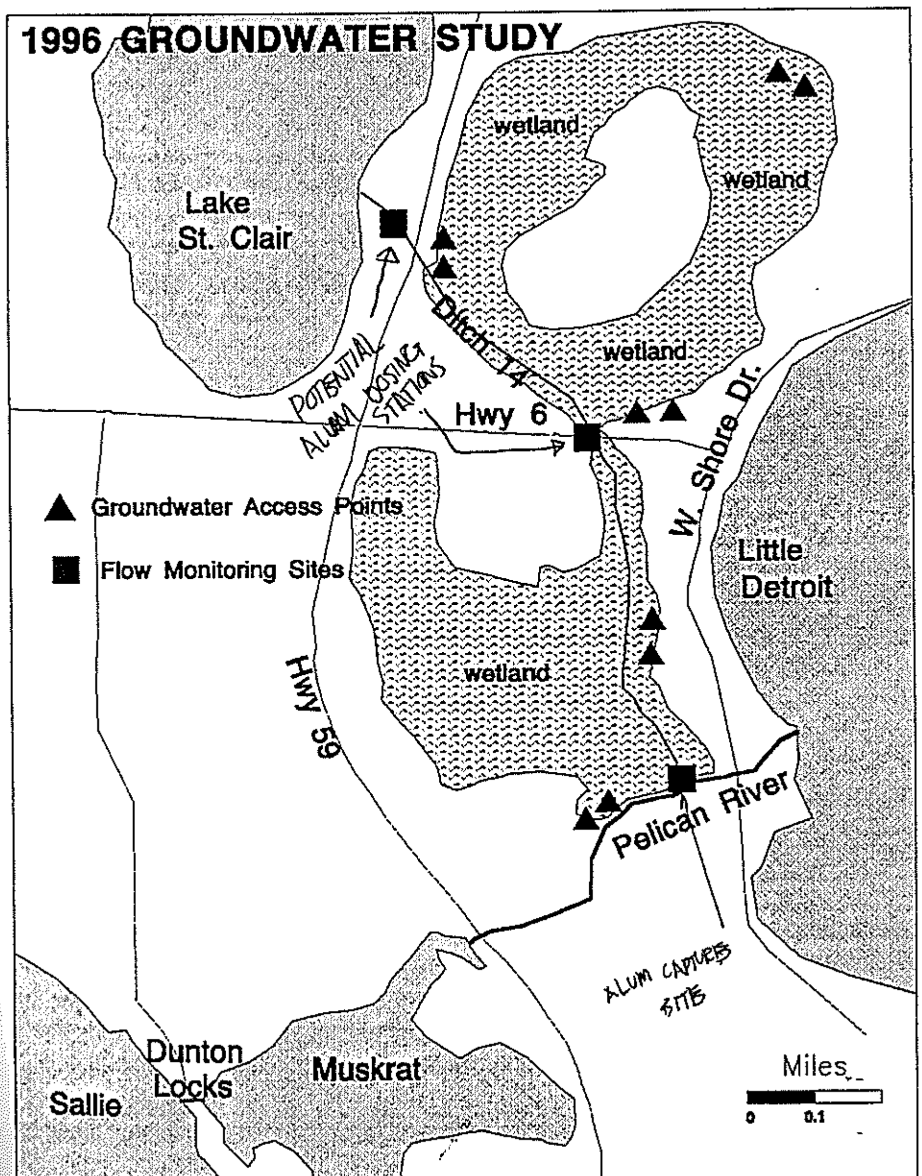


Figure 32. Potential locations for installing an alum dosing station on Ditch 14.

Figure 33. Potential staging sites for an alum dosing station near Hwy 6. Alum tanks would be located on upland areas [top] and a dosing line would feed into Ditch 14 near the culvert at Hwy 6. The alum floc would be captured in a subsurface trap near the mouth of Ditch 14.

4c. In-lake alum treatment of Lake Sallie
The last reserve project that would be considered for improving water quality in Lake Sallie is an alum treatment. This would reduce nuisance algae blooms by reducing internal loading. Many shallow lakes like Lake Sallie have been successfully treated with alum over the last twenty years. However, as drawbacks there is a possibility of adversely impacting the benthic invertebrate community which, ultimately, could effect the high quality walleye population. Also a whole-lake alum treatment would be expensive. This project is a reserve project and would be considered only after other options were installed and were not working to reduce internal loading.

Costs: An alum treatment in Lake Sallie would use a dose of about 400 gallons liquid alum per surface acre. Jar tests would be conducted to insure pH and aluminum concentrations were not dangerous. The estimated cost is about $400 per acre and about 1,000 acres would be treated. An estimated total project cost would be approximately $400,000.

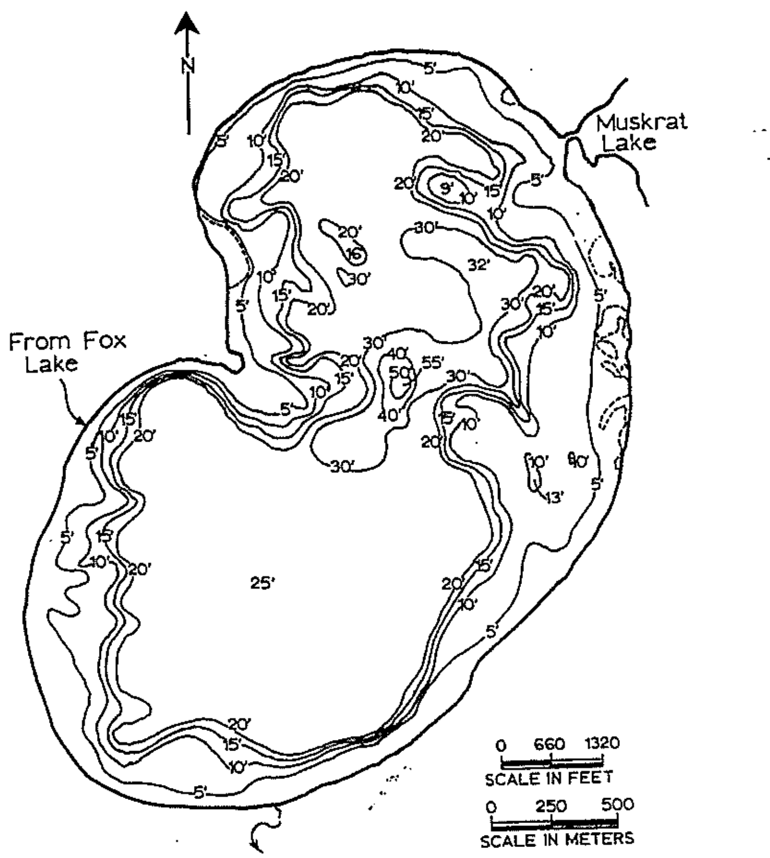


Figure 34. Approximately 1,000 acres of the 1,200 acre Lake Sallie would be treated with alum, approximately all depths greater than four feet.

3.4. Information and Education Program

The Pelican River Watershed District has a vigorous ongoing information and education program. A number of pamphlets and newsletters have been produced over the years.

The primary purpose of the Lake Sallie Information and Education Program is to communicate lake and watershed plan and the water quality benefits to potential watershed co-operators, community leaders, and the general public.

Information would continue to be distributed to homeowners around Lake Sallie to prevent pollution of the lake from yard chemicals (pesticides and fertilizers) and cultural activities near the lake.

The goals of the Lake Sallie Information and Education Program are:

□ Educate watershed residents regarding nonpoint pollution sources to the lakes and streams and in the watershed.

□ Increase the awareness and understanding of Lake Sallie and its watershed as an ecosystem, its water quality problems and the benefits achieved using best management practices through integrated resource management.

□ Inform residents about the potential for water quality improvement, and instill a sense of stewardship for natural resources within the Lake Sallie Watershed.

□ Coordinate and cooperate with other federal, state and local governmental agencies and their nonpoint source pollution control programs and advocate all suitable governmental program plans of action as ways to implement and achieve improved water quality for Lake Sallie.

To achieve the goals of this program, a number of activities are planned and include:

I. Newsletters:

II. Fact Sheets:

III. Area School Participation:

IV. Media:

Costs: The estimated cost for the Information and Education Program is **$23,000**. This is based on a six-year program. The cost breakdown is shown below.

Information and Education Program budget

	Total
Newsletter (1 per year, plus an extra if needed)	**$12,000**
Fact Sheets (prepare 6-8 fact sheets, mail with newsletter)	**$6,000**
Area School Participation (coordinate Middle School and High School field exercises)	**$3,000**
Media (newspaper articles -- four minimum)	**$2,000**
Total Cost	**$23,000**

3.5. Monitoring and Evaluation Procedures

Several project areas will be monitored over the course of this project to evaluate projects and to check Lake Sallie.

One of the best tests for evaluating Lake Sallie improvements may be using secchi disc readings to see if water clarity improves. However, other sampling will be conducted as well including redox measurements and occasional iron readings and oxygen demand tests.

The Pelican River Watershed District will continue to monitor watershed runoff to see if and how nutrients are being reduced. Some of the watershed sampling will be conducted in conjunction with evaluating specific projects. Projects that have specific monitoring needs are shown in Table 17. Because several of these projects are new, specific data collection is necessary.

Table 17. Projects with monitoring needs.

	Monitoring Needs	
	Yes	No
1. Implementation Project		
1.a. Detroit Lake storm water runoff treatment installation	X	
1.b. Septic system monitoring/upgrades/sewer conversions		X
1.c. Shoreland zone management practices		X
1.d. Improve feedlot and other agricultural practices		X
1.e. Streambank protection and stabilization	X	
2.a. Lake St. Clair alum treatment	X	
2.b. Improve boat landing and conduct harvesting on Muskrat Lake	X	
2.c. Winter aerator, for Muskrat Lake, combined with stocking	X	
2.d. Wetland projects		X
3.a. Aquatic plant harvesting	X	
3.b. Control of Flowering Rush	X	
3.c. Continued lake sampling for trend analysis	X	
4.a. Muskrat Lake alum treatment	X	
4.b. Alum dosing on Ditch 14	X	
4.c. Lake Sallie alum treatment	X	

Costs: The cost for monitoring Lake Sallie evaluating proposed projects over the next six years is **$78,000**.

Routine monitoring for the next six years will continue to employ the existing network of sampling stations. It is estimated that annual costs are $8,000 per year for a six year total of $48,000.

Project evaluation is another area to monitor. We will employ biocriteria as well as water chemistry testing for specifically monitoring streambank erosion control, stormwater runoff treatment, and nutrient export from feedlot sources. This monitoring and evaluation will complement other types of monitoring and give some insight to interpreting water quality trends. The annual cost $5,000 for a six year total of $30,000/

The combined cost of routine monitoring and project evaluation is $78,000.

3.6. Project Management

Roles and Responsibilities of Project Participants: The framework for managing this project is well established. The administrator of the Pelican River Watershed District, Dick Hecock, would be the project contact and the Watershed District would be the Local Project.

The roles and responsibilities of project participants are summarized in the Milestone Schedule (next section in Table 19).

Operation and Maintenance: Some projects that are recommended to be implemented require operation and maintenance costs. The list of projects and projects with O & M costs are shown in Table 18.

Table 18. Projects with operation and maintenance needs.

Alternative	Operation and Maintenance Required in Phase 2 No	Yes
1. Implementation Project		
1.a. Detroit Lake storm water runoff treatment installation		X
1.b. Septic system monitoring/upgrades/sewer conversions		X
1.c. Shoreland zone management practices		X
1.d. Improve feedlot and other agricultural practices		X
1.e. Streambank protection and stabilization		X
2.a. Lake St. Clair alum treatment	X	
2.b. Improve boat landing and conduct harvesting on Muskrat Lake		X
2.c. Winter aerator, for Muskrat Lake, combined with stocking		X
2.d. Wetland projects	X	
3.a. Aquatic plant harvesting		X
3.b. Control of Flowering Rush		X
3.c. Continued lake sampling for trend analysis		X
4.a. Muskrat Lake alum treatment	X	
4.b. Alum dosing on Ditch 14		X
4.c. Lake Sallie alum treatment	X	

Permits, Legal Authority, Etc.: For the implementation plan to accomplish its objectives several conditions must be met and these include

- ☐ District funding will need to be secured for some of the projects.
- ☐ MnDNR permits will be needed for projects 2a, 2b, and 2c.
- ☐ The District already secures the necessary permits for aquatic plant harvesting.

COSTS: The estimated cost for Project Management element is **$50,000**. This is based on a six-year program. Costs are for project administration, meetings, and reports over the six year project period.

3.7. Implementation Program

The Lake Sallie Implementation Plan is designed to improve water quality in Lake Sallie so it can be brought into ecoregion averages. To reach this goal, twelve projects have been proposed with three projects on "reserve" to be implemented only if necessary. An information and education program would be ongoing. In addition, a monitoring program has been designed to test the effectiveness of the projects and to check to see if project goals are to be achieved. Another component is project management which includes project administration, field inspections, quarterly reports and mid project and final reports. The total cost for this project is estimated at $1,198,000. The cost summary is shown at the end of this section.

Program Elements: The Lake Sallie Implementation Plan has four primary Program Elements with each element having sublistings. The four elements are:

1. Watershed and Lake Projects.
2. Information and Education Program.
3. Monitoring and Evaluation Procedure.
4. Project Management.

Milestone Schedule: The Lake Sallie implementation project is scheduled for a six year time period. The milestone schedule is shown in Table 19. Some projects have different starting times, and some projects are dependent on the success of earlier projects. The sequencing of projects is shown below on the time line.

Table 19. Milestone schedule for the implementation plan. The schedule is based on a 6-year (72 month) schedule. PRWD = Pelican River Watershed District.

Activity	Time Frame (months)	Responsible Group
Kick Off Meeting	1	PRWD
1. Implementation Project		
1. Watershed BMPs		
1a. Detroit Lake storm water runoff treatment installation	6-72	PRWD/Consultants
1.b. Septic system monitoring/upgrades/sewer conversions	6-72	PRWD/County
1.c. Shoreland zone management practices	6-72	MnDNR/PRWD
1.d. Improve feedlot and other agricultural practices	6-72	SWCD
1.e. Streambank protection and stabilization	6-72	SWCD
2. Special Watershed BMPs		
2.a. Lake St. Clair alum treatment	12-20	PRWD
2.b. Improve boat landing and conduct harvesting on Muskrat Lake	12-72	PRWD
2.c. Winter aerator, for Muskrat Lake	12-18	PRWD/MnDNR
2.d. Wetland projects	12-30	PRWD/MPCA
3. On-going Lake Sallie Projects		
3.a. Aquatic plant harvesting	12-72	PRWD
3.b. Control of Flowering Rush	12-72	PRWD
3.c. Continued lake sampling for trend analysis	4-72	PRWD
4. Reserve Projects		
4a. Muskrat Lake alum treatment	36-48	PRWD
4b. Alum dosing on Ditch 14	48-60	PRWD
4c. Lake Sallie alum treatment	60-70	PRWD
5. Information and Education Program	4-72	PRWD/others
6. Monitoring	1-72	PRWD/MPCA
7. Project Management		
Admin & Meetings	4-72	PRWD
Reports	12-72	PRWD/Consultant
Mid Project Review	36	PRWD/MPCA/Others
Final Report	60-72	PRWD/Others

Implementation Plan Budget: The estimated cost for the Lake Sallie Implementation Project is $1,198,000. The cost represents in-kind services, cash to be supplied through an MPCA grant, an MPCA loan, cash from State and Federal Cost Share Programs, and cash supplied by the Pelican River Watershed District. A summary of costs for the Implementation Plan is shown in Table 20.

Table 20. Phase II Budget for Lake Sallie.

Program Element	Project Cost	State/ Federal (in-kind)	Local (in-kind)	Local (cash)	MPCA (cash)	MPCA (loan)
1. Implementation Projects						
1. Watershed BMPs **1.a.** Detroit Lake storm water runoff treatment installation	170,000	0	0	0	0	170,000
1.b. Septic system monitoring/upgrades/sewer conversions	8,000	0	0	8,000	0	0
1.c. Shoreland zone management practices	10,000	2,000	8,000	0	0	0
1.d. Improve feedlot and other agricultural practices	60,000	40,000		20,000	0	0
1.e. Streambank protection and stabilization	12,000	0	6,000	6,000	0	0
2. Special Watershed BMPs **2.a.** Lake St. Clair alum treatment	40,000	0	0	0	0	40,000
2.b. Improve boat landing and conduct harvesting on Muskrat Lake	22,000	0	0	0	6,000	16,000
2.c. Winter aerator for Muskrat Lake	33,000	0	0	0	0	33,000
2.d. Wetland projects	33,000	0	3,000	0	30,000	0
3. On-going Lake Sallie Projects **3.a.** Aquatic plant harvesting	60,000	0	60,000	0	0	0
3.b. Control of Flowering Rush	60,000	0	60000	0	0	0
3.c. Continued lake sampling for trend analysis	18,000	0	6,000	0	12,000	0
4. Reserve Projects **4a.** Muskrat Lake alum treatment	26,000	0	0	0	0	26,000
4b. Alum dosing on Ditch 14	100,000	0	0	0	0	100,000
4c. Lake Sallie alum treatment	400,000	0	0	0	0	400,000
5. Information Education	23,000	0	12,000	11,000	0	0
6. Monitoring **6a.** Routine lake and watershed	48,000	0	24,000	24,000	0	0
6b. Project evaluation	30,000	2,000	10,000	12,000	6,000	0
7. Project Management **7a.** Project meetings/administration	15,000	0	10,000	5,000	0	0
7b. Reports	22,000	2,000	14,000	6,000	0	0
7c. Printing & Mailing	8,000	0	0	8,000	0	0
TOTALS	1,198,000	46,000	213,000	100,000	54,000	785,000

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Appendices

A. Stream and Ditch Water Quality for 1994-1996

B. Results of the 1996 Study of Wetland Groundwater Discharge to Ditch 14

C. Muskrat Lake and Lake St. Clair Background Information

D. BATHTUB and FLUX Runs for 1995 and 1996

Appendix A

Stream and Ditch Water Quality Data for 1994-1996

1996 Lake Sallie Watershed water quality data.

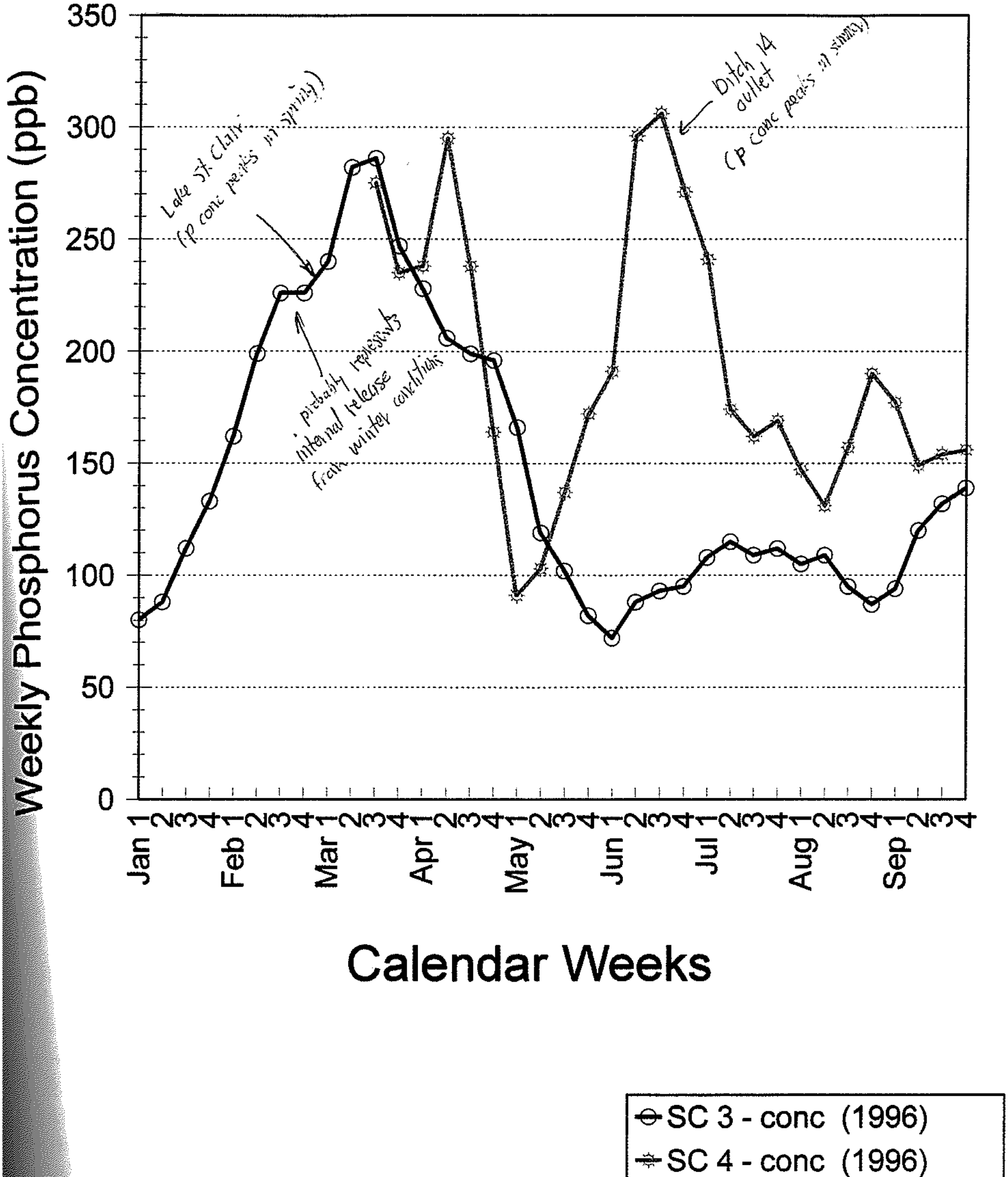
Weeks	SC 3 (Lake St. Clair Outlet to Ditch 14)			Ditch D (Wetland Outlet to Ditch 14 Est)		SC 4 (Ditch 14 Outlet)			PR 6 (Detroit Lake Outlet to Pelican River)			PR 7 (Muskrat lake Outlet to Dunston Locks)			SC 4 + PR 6 (est)
	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Flow (cfs)	Load (lb/wk)	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Load (lb/wk)
Jan 1	4.8	80	14.6	--	--	--	--	--	--	--	--	--	--	--	
2	4.8	88	16.2	--	--	--	--	--	27.5	10	4.6	31.7	12	8.4	20.8
3	4.8	112	20.6	--	--	--	--	--	--	--	--	0	0	0	20.6
4	6.2	133	47.9	--	--	--	--	--	41.2	15	19.9	28.6	23	10.5	67.8
Feb 1	7.0	162	42.3	--	--	--	--	--	29.5	18	8.6	24.0	39	10.0	50.9
2	6.0	199	44.5	--	--	--	--	--	24.8	25	13.0	29.0	49	52.2	57.5
3	4.4	226	37.0	--	--	--	--	--	16.8	25	9.0	30.0	54	61.2	46.0
4	3.9	226	39.0	--	--	--	--	--	13.7	24	8.9	25.8	58	15.9	47.9
Mar 1	5.5	240	50.0	--	--	--	--	--	20.3	23	12.4	0	0	0	70.3
2	4.5	282	48.9	--	--	--	--	--	17.8	29	19.3	22.6	88	32.2	68.2
3	3.5	286	36.8	2.9	39.3	6.4	275	76.1	15.4	36	21.0	24.8	86	80.3	97.1
4	4.1	247	56.6	2.3	24.1	6.4	235	80.7	17.3	40	37.5	29.1	69	107.8	118.2
Apr 1	5.0	228	42.3	6.9	66.2	11.9	238	108.5	18.9	30	21.0	30.9	83	100.0	129.5
2	8.9	206	66.4	4.6	83.1	13.5	295	149.5	27.3	30	30.8	40.3	124	189.6	180.3
3	11.6	199	87.2	3.4	39.2	15.0	238	126.4	44.0	32	53.3	59.3	95	206.3	185.7
4	11.3	196	107.2	3.7	12.2	15.0	164	119.4	54.8	29	77.7	73.5	59	210.2	197.1
May 1	9.4	166	59.1	3.9	-13.0	13.3	91	46.1	55.2	20	42.5	72.4	36	99.1	88.6
2	6.8	119	30.6	5.3	16.7	12.1	103	47.3	51.8	21	40.6	70.5	40	106.0	87.9
3	7.3	102	28.0	8.0	52.6	15.3	137	80.6	68.4	23	61.0	74.6	36	99.9	141.6
4	6.4	82	28.7	9.0	114.1	15.4	172	142.8	68.5	25	90.6	81.6	39	171.4	233.4
Jun 1	5.4	72	14.8	6.3	70.3	11.7	191	85.1	55.0	30	63.1	69.7	47	123.2	148.2
2	5.3	88	17.5	6.4	112.2	11.7	296	129.7	52.4	32	63.4	64.9	51	123.8	193.1
3	4.1	93	14.5	5.1	93.0	9.2	306	107.5	44.6	15	26.1	52.0	45	88.2	133.6
4	3.7	95	16.6	3.2	74.4	6.9	271	91.0	34.7	10	16.4	41.5	41	82.8	107.4
Jul 1	2.8	108	11.4	2.3	35.0	5.1	241	46.4	24.5	19	17.2	32.1	45	53.6	63.6
2	2.4	115	10.2	1.3	17.8	3.7	174	28.0	17.0	28	17.8	23.6	56	49.6	45.8
3	2.1	109	7.5	1.3	13.3	3.4	162	20.8	11.8	31	13.6	20.6	58	45.7	34.4
4	1.6	112	9.4	1.1	7.5	2.7	169	16.9	9.3	29	14.7	15.5	49	40.7	31.6
Aug 1	1.6	105	6.4	1.4	17.5	3.0	147	23.9	11.0	26	10.5	17.8	42	28.2	34.4
2	1.3	109	6.1	1.3	6.9	2.6	131	13.0	8.2	18	5.8	14.7	32	18.0	18.8
3	1.2	95	4.3	0.8	7.7	2.0	157	12.0	3.4	12	1.4	8.0	28	8.5	13.4
4	1.0	87	4.9	0.8	13.6	1.8	190	18.5	0.8	20	1.0	4.8	34	8.4	19.5
Sep 1	1.2	94	4.4	1.2	11.8	2.4	177	16.2	4.3	28	4.6	12.4	40	18.6	20.6
2	1.2	120	5.2	0.9	6.6	2.1	149	11.8	2.2	23	2.0	9.6	42	14.9	13.8
3	1.0	132	5.0	0.5	5.6	1.5	154	10.6	0	7.6	0	1.9	51	3.4	10.6
4	1.3	139	8.7	0.9	7.6	2.2	156	16.3	0	30	0	6.8	60	20.5	16.3

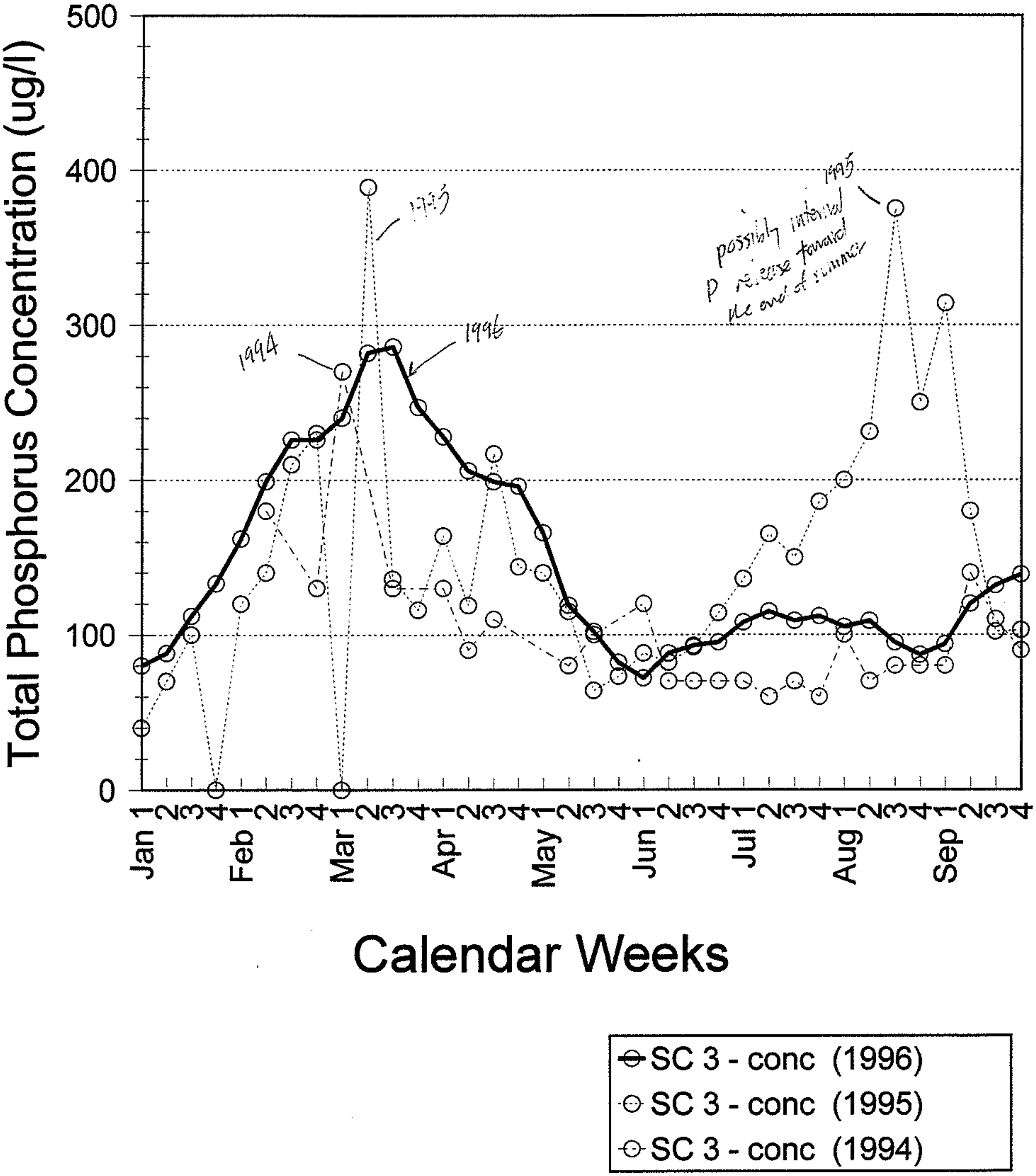
5 Lake Sallie Watershed water quality data.

	SC 3 (Lake St. Clair Outlet to Ditch 14 -- 1996 curve)			Ditch D (Wetland Outlet to Ditch 14 Est)		SC 4 (Ditch 14 Outlet)			PR 6 (Detroit Lake Outlet to Pelican River)			PR 7 (Muskrat lake Outlet to Dunston Locks) (1996 curve)			SC 4 + PR 6 (est)	
eeks	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Flow (cfs)	Load (lb/wk)	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Load (lb/wk)	
n 1	–	40	0	–	–	–	–	–	17.6	10	5.7	32.6	20	21.1		5.7
	2.2	70	0.8	–	–	–	60	–	18.7	10	7.1	32.6	20	24.6		7.1
	–	100	0	–	–	–	80	–	18.7	20	14.1	32.0	20	24.6		14.
	–	0	0	–	–	–	–	–	17.6	10	6.6	30.8	20	23.3		6.6
b 1	–	120	0	–	–	–	–	–	16.4	10	6.0	28.9	20	21.9	–	6.0
	–	140	0	–	–	–	–	–	15.2	20	11.3	28.9	30	32.8	–	11.3
	–	210	0	–	–	–	–	–	15.2	20	11.3	28.9	30	32.8	–	11.3
	1.7	230	2.0	–	–	–	–	–	13.1	10	5.2	27.1	40	41.0	–	5.2
ar 1	–	0	0	–	–	–	–	–	16.4	10	12.1	28.9	70	144.1	–	12.1
	2.9	389	18.4	3.2	-17.4	6.1	494	1.0	18.7	312	94.4	30.1	401	200.0	95.4	
	4.8	136	38.8	5.8	39.2	10.6	124	78.0	38.5	14	32.7	61.8	35	130.0	110.7	
	6.2	116	27.1	6.8	40.9	13.0	140	68.0	44.9	17	31.5	72.7	36	99.0	99.5	
pr 1	4.7	164	28.9	7.7	25.1	12.4	115	54.0	49.9	23	42.7	70.9	38	102.0	96.7	
	4.7	119	20.9	7.7	25.1	12.4	98	46.0	49.9	8	14.8	69.1	33	86.2	60.8	
	4.2	217	34.7	7.7	24.3	11.9	132	59.0	45.4	27	46.3	67.3	32	61.4	105.3	
	3.4	144	18.2	8.0	28.2	11.4	109	47.0	41.9	16	25.3	63.6	22	52.9	72.3	
ay 1	3.2	140	17.1	10.4	55.0	13.6	180	72.1	35.2	19	26.5	60.0	30	68.0	98.6	
	3.5	115	15.1	9.8	40.2	13.3	142	55.3	35.2	14	19.5	56.3	31	66.0	74.8	
	3.8	64	7.9	9.3	23.3	13.1	96	31.2	35.2	13	16.1	56.3	20	42.6	47.3	
	4.5	73	14.2	-1.2	26.6	3.3	103	40.8	33.7	16	20.1	54.5	26	53.6	60.9	
n 1*	4.5	88	27.3	-0.9	75.7	3.6	205	103.0	23.1	13	18.9	42.0	29	88.9	121.9	
	3.8	82	11.9	4.1	32.1	7.9	147	44.0	23.7	13	12.8	34.4	36	46.8	56.8	
	2.7	92	9.5	3.9	62.5	6.6	287	72.0	13.7	200	141.2	19.8	44	33.0	213.2	
	1.6	114	7.0	3.2	25.0	4.8	176	32.0	11.7	20	8.6	16.2	46	28.1	40.6	
l 1	3.6	136	18.7	0.9	15.3	4.5	202	34.0	3.4	18	6.1	25.3	48	45.9	40.1	
	3.6	165	26.0	2.2	18.0	5.8	199	44.0	16.4	16	9.6	30.8	50	58.1	53.6	
	3.6	150	17.4	2.0	19.0	5.6	173	36.4	15.2	23	13.1	28.9	36	39.4	49.5	
	2.7	186	19.1	2.6	18.7	5.3	190	37.8	13.0	30	15.0	21.6	36	29.5	52.8	
g 1*	1.9	200	28.7	1.3	25.3	3.2	236	54.0	4.3	22	6.8	8.0	37	23.3	60.8	
	1.3	231	11.3	0.0	1.7	1.3	259	13.0	0.0	28	0.0	0.0	55	0.0	13.0	
	2.1	375	30.0	-1.4	-23.0	0.7	290	7.0	0.0	22	0.0	13.4	40	20.3	7.0	
	3.8	250	36.2	3.3	37.8	7.1	274	74.0	10.6	33	24.1	35.5	70	86.7	98.1	
p 1	5.6	314	57.2	0.8	-46.2	6.4	39	11.0	13.7	39	31.5	30.8	86	85.7	42.5	
	3.7	180	21.6	2.0	5.4	5.7	147	27.0	11.7	35	12.9	23.5	81	61.6	39.9	
	2.6	102	11.6	1.2	2.5	3.8	85	14.1	0.7	36	6.3	12.5	60	32.4	20.4	
	1.9	103	6.3	1.7	5.7	3.6	80	12.0	0.2	35	0.6	8.9	58	22.2	12.6	
ay interval																
3 - Sept 4 →			563		673			1167			583			1464	1750	

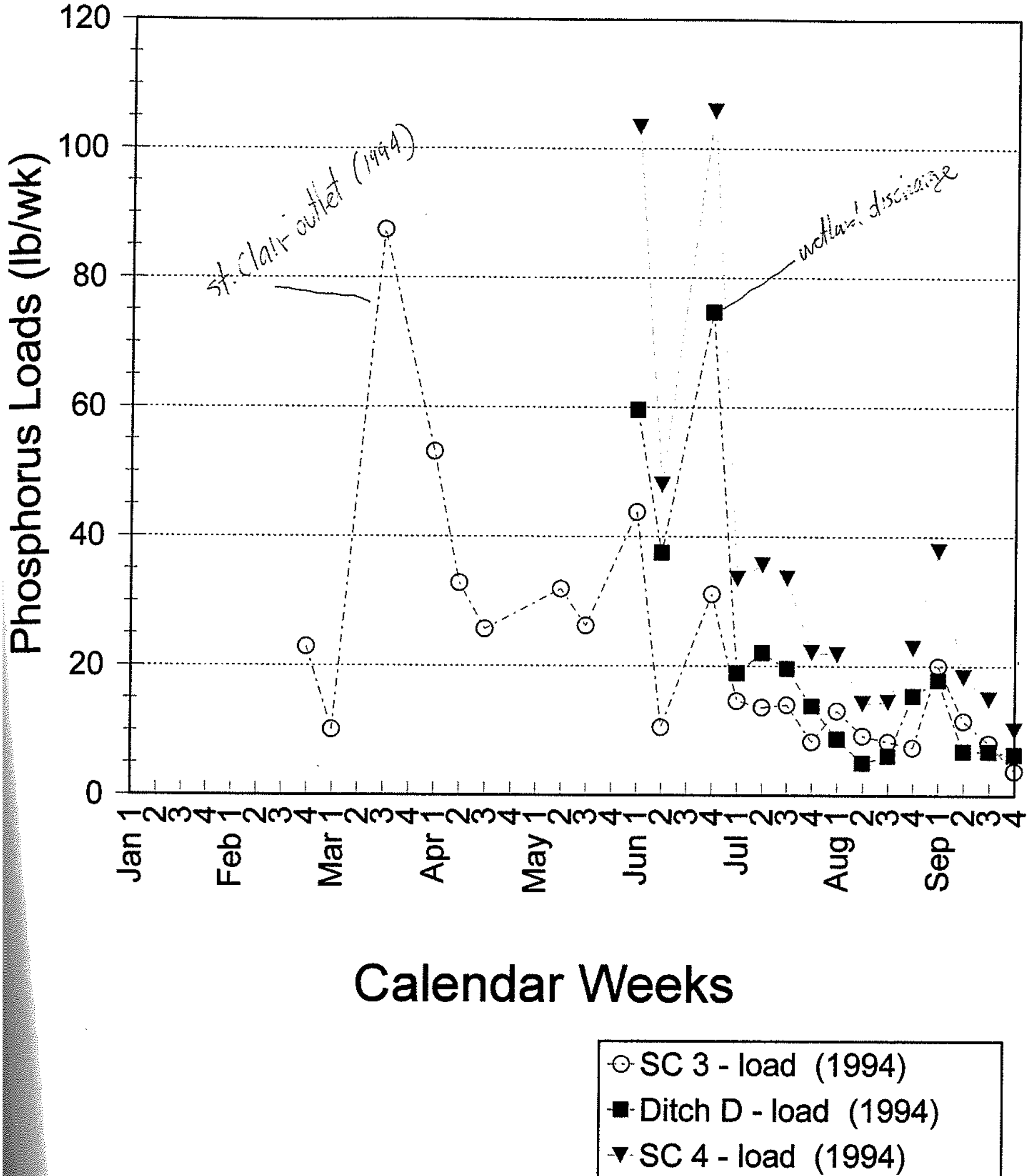
1994 Lake Sallie Watershed water quality data.

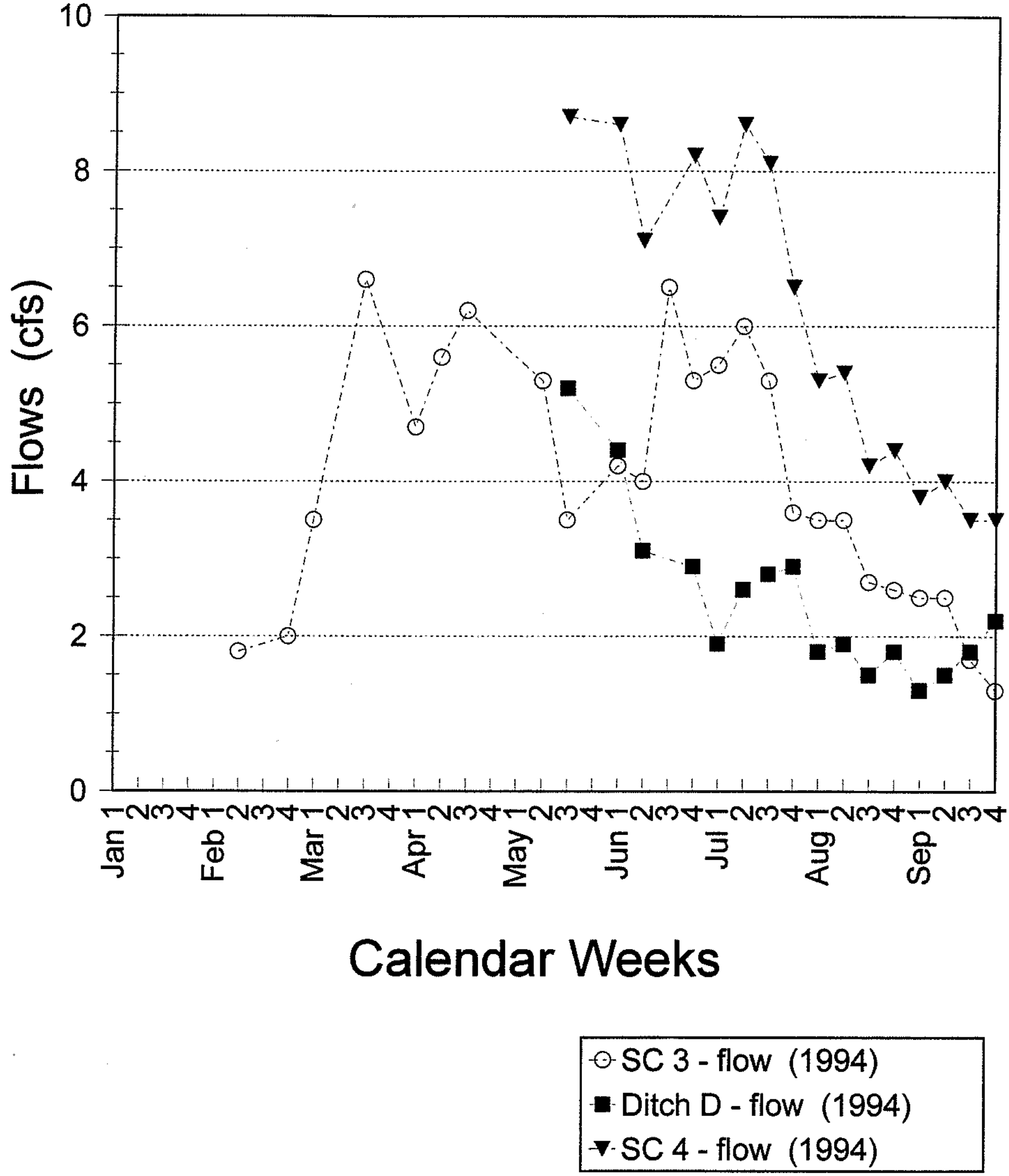
Weeks	SC 3 (Lake St. Clair Outlet to Ditch 14)			Ditch D (Wetland Outlet to Ditch 14 Est)		SC 4 (Ditch 14 Outlet)			PR 6 (Detroit Lake Outlet to Pelican River)			PR 7 (Muskrat lake Outlet to Dunston Locks)			SC 4 + PR 6 (est)
	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Flow (cfs)	Load (lb/wk)	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Flow (cfs)	Conc (ug/l)	Load (lb/wk)	Load (lb/wk)
Jan 1	–	–	–	–	–	–	–	–				–	–	–	
2	–	–	–	–	–	–	–	–				–	–	–	
3	–	–	–	–	–	–	–	–				–	–	–	
4	–	–	–	–	–	–	–	–				–	–	–	
Feb 1	–	–	–	–	–	–	–	–				–	–	–	
2	1.8	180	–	–	–	–	–	–				–	–	–	
3	–	–	–	–	–	–	–	–				–	–	–	
4	2.0	130	22.9	–	–	–	–	–				–	–	–	
Mar 1	3.5	270	10.1	–	–	–	–	–				–	–	–	
2	–	–	–	–	–	–	–	–				–	–	–	
3	6.6	130	87.4	–	–	–	–	–				–	–	–	
4	–	–	–	–	–	–	–	–				–	–	–	
Apr 1	4.7	130	53.1	–	–	–	–	–				–	–	–	
2	5.6	90	32.8	–	–	–	–	–				–	–	–	
3	6.2	110	25.7	–	–	–	–	–				–	–	–	
4	–	–	–	–	–	–	–	–				–	–	–	
May 1	–	–	–	–	–	–	–	–				–	–	–	
2	5.3	80	31.9	–	–	–	–	–				–	–	–	
3	3.5	100	26.2	5.2	–	8.7	8	–				–	–	–	
4	–	–	–	–	–	–	–	–				–	–	–	
Jun 1*	4.2	120	43.8	4.4	59.6	8.6	320	103.4				50.9	50	–	
2	4.0	70	10.5	3.1	37.5	7.1	180	48.0				–	–	–	
3	6.5	70	–	–	–	–	–	–				43.6	30	98.7	
4	5.3	70	31.1	2.9	74.7	8.2	170	105.8				38.1	50	71.9	
Jul 1	5.5	70	14.6	1.9	18.9	7.4	130	33.5				41.7	60	94.6	
2	6.0	60	13.6	2.6	22.0	8.6	110	35.6				35.4	50	66.7	
3	5.3	70	14.0	2.8	19.6	8.1	110	33.6				36.3	40	54.7	
4	3.6	60	8.3	2.9	13.8	6.5	90	22.1				28.1	40	42.4	
Aug 1	3.5	100	13.1	1.8	8.7	5.3	110	21.8				27.1	40	41.0	
2	3.5	70	9.2	1.9	5.0	5.4	70	14.2				31.7	40	47.9	
3	2.7	80	8.3	1.5	6.1	4.2	90	14.4				18.0	30	20.4	
4	2.6	80	7.4	1.8	15.4	4.4	110	22.8				18.0	30	20.4	
Sep 1	2.5	80	20.0	1.3	17.8	3.8	110	37.8				16.2	30	45.6	
2	2.5	140	11.5	1.5	6.8	4.0	140	18.3				18.0	40	23.3	
3	1.7	110	8.1	1.8	6.8	3.5	100	14.9				12.5	40	21.6	
4	1.3	90	3.8	2.2	6.3	3.5	90	10.1				9.9	30	8.6	

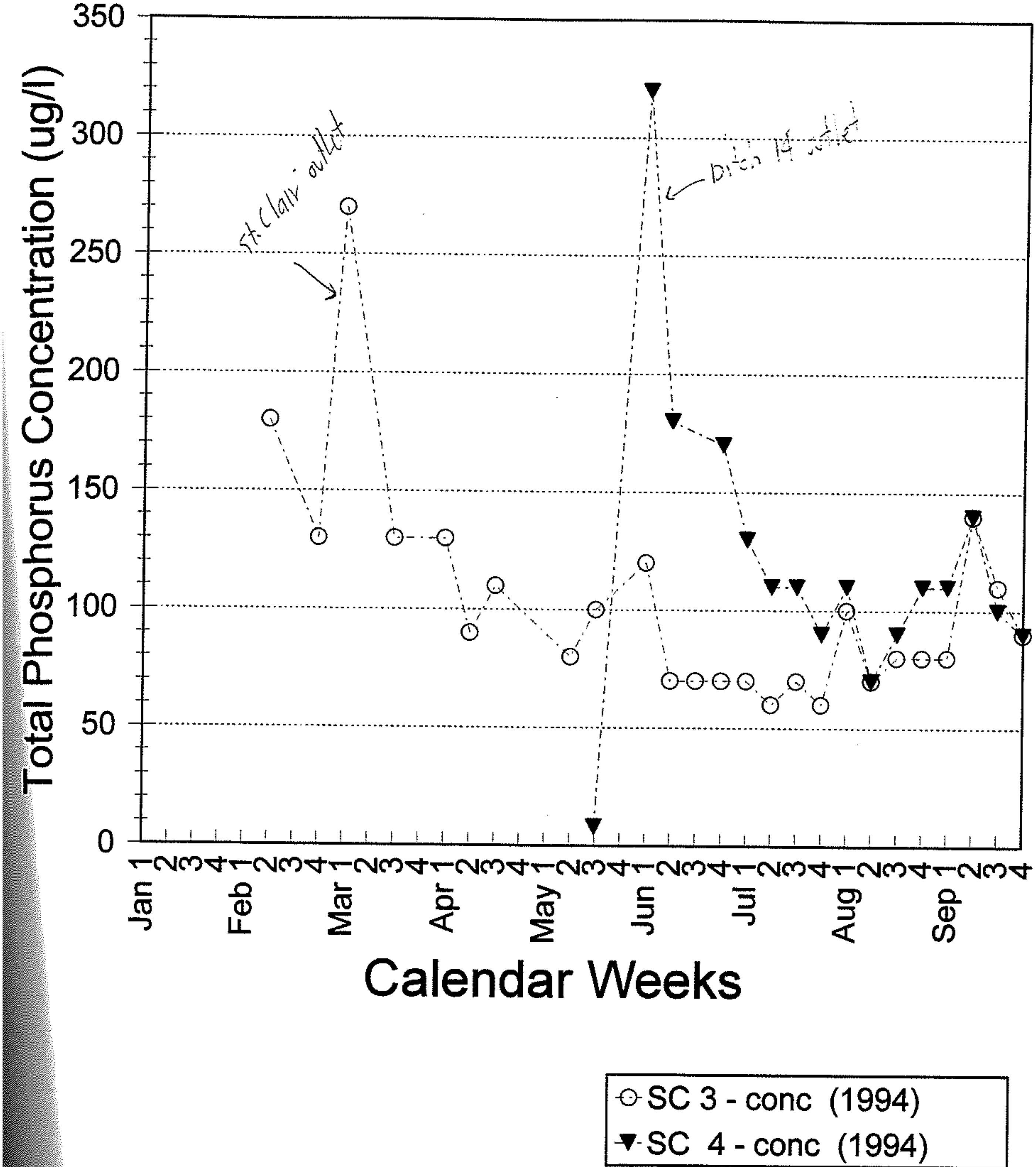

Weekly Phosphorus Concentration (ppb)
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Calendar Weeks
SC 3 - conc (1996)
SC 4 - conc (1996)
Ditch 14 outlet
Lake St. Clair



Total Phosphorus Concentration (ug/l)
500
400
300
200
100
0
1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Calendar Weeks
SC 3 - conc (1996)
SC 3 - conc (1995)
SC 3 - conc (1994)
1994
1995
1996
1995
possibly internal P release toward the end of summer


Phosphorus Loads (lb/wk)
Calendar Weeks
st. Clair outlet (1994)
wetland discharge
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
SC 3 - load (1994)
Ditch D - load (1994)
SC 4 - load (1994)


10
8
6
4
2
0
Flows (cfs)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
1 2 3 4
Calendar Weeks
SC 3 - flow (1994)
Ditch D - flow (1994)
SC 4 - flow (1994)



Total Phosphorus Concentration (ug/l)
350
300
250
200
150
100
50
0
St. Clair outlet
Ditch 14 outlet
Jan 1 2 3 4
Feb 1 2 3 4
Mar 1 2 3 4
Apr 1 2 3 4
May 1 2 3 4
Jun 1 2 3 4
Jul 1 2 3 4
Aug 1 2 3 4
Sep 1 2 3 4
Calendar Weeks
SC 3 - conc (1994)
SC 4 - conc (1994)

Appendix B

Results of the 1996 Study of Wetland Groundwater Discharge to Ditch 14

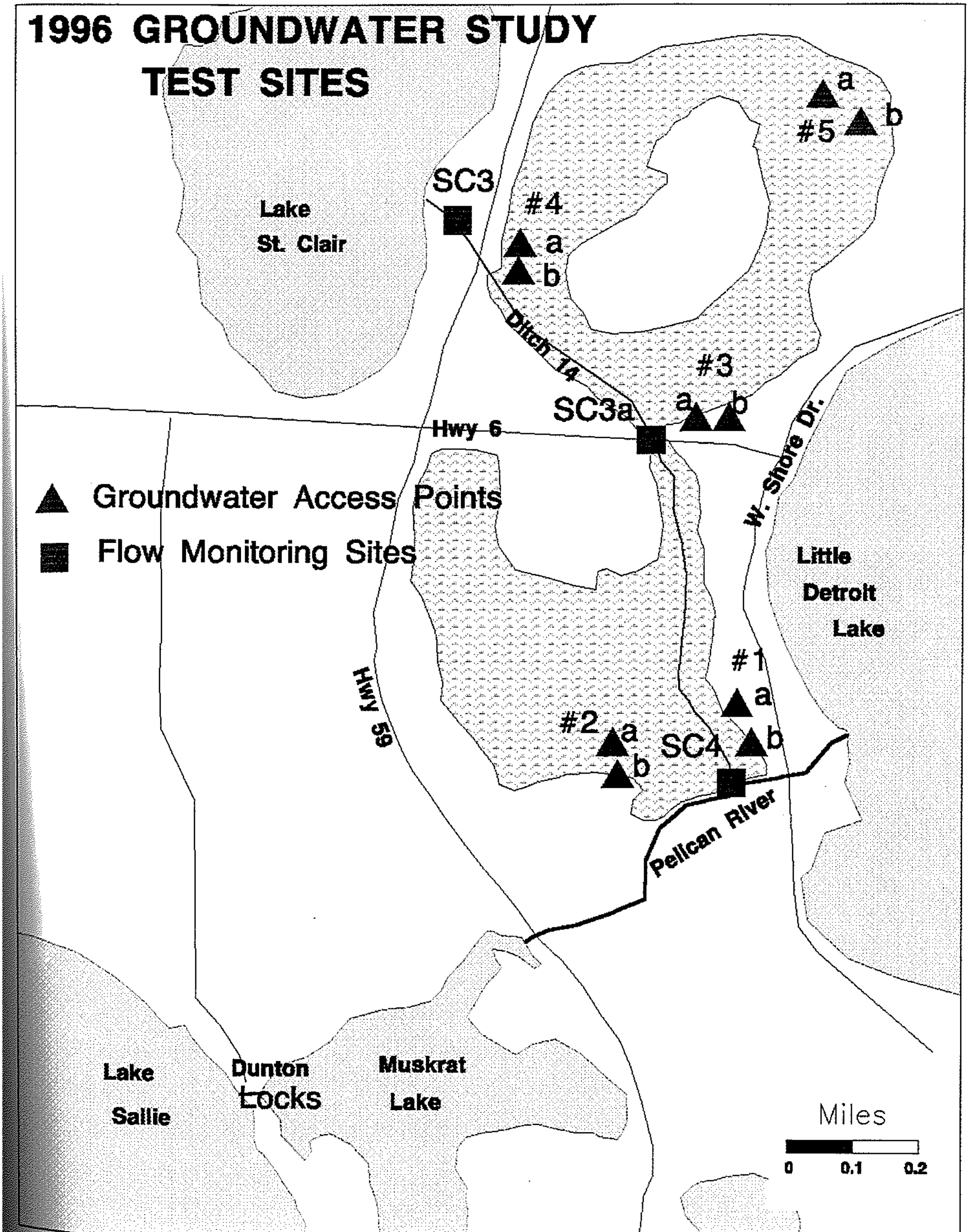
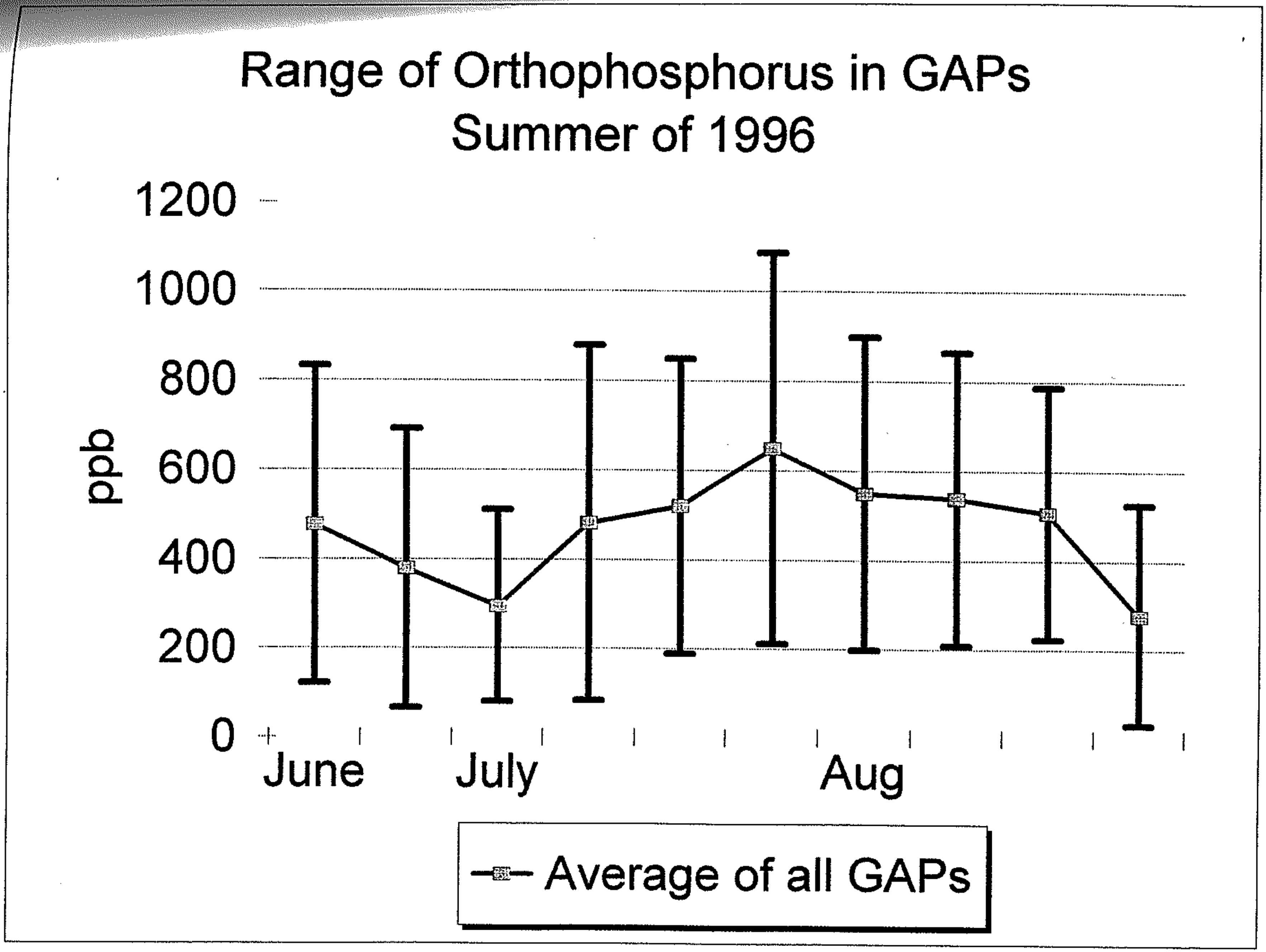

1996 GROUNDWATER STUDY
TEST SITES
Lake
St. Clair
SC3
#4
a
b
#5
a
b
Ditch 14
#3
a
b
SC3a
Hwy 6
W. Shore Dr.
Groundwater Access Points
Flow Monitoring Sites
Little
Detroit
Lake
Hwy 59
#1
a
b
#2
a
b
SC4
Pelican River
Lake
Sallie
Dunton
Locks
Muskrat
Lake
Miles
0
0.1
0.2

Table . Groundwater access point data in Ditch 14 discharge area between Lake St. Clair (SC 3) and Ditch 14 outlet to the Pelican River (SC 4). TP = total phosphorus, OP = orthophosphorus. Concentrations are shown in ug/l.

	June				July								August		October	
	17		24		1		8		15		29		15			
Wells	TP	OP	TP	OP	TP	OP	TP	OP	TP	OP	TP	OP	TP	OP	TP	OP
1a	--	371	--	313	402	--	682	651	498	414	1,112	1,087	842	732		
1b	--	531	--	528	623	--	662	646	742	696	924	859	956	898		
2a	--	366	--	341	446	--	302	270	596	523	802	768	762	688		
2b	--	246	--	188	253	--	468	431	252	190	299	269	259	198		
3a	--	366	--	298	380	--	362	297	802	713	598	505	558	435		
3b	--	831	--	693	791	--	1,478	878	302	226	542	498	489	399		
4a	--	356	--	300	417	--	442	429	656	595	523	485	--	--		
4b	--	308	--	331	560	--	501	478	532	481	602	554	--	--		
5a	--	122	--	168	239	--	401	367	989	848	1,002	965	843	768		
5b	--	474	--	66	99	--	102	84	302	221	314	212	312	202		

Surface	June						July										August			
	13		20		27		3		11		18		26		30		8		14	
Stations	TP	OP	TP	OP	TP	OP	TP	OP	TP	OP	TP	OP	TP	OP	TP	OP	TP	OP	TP	OP
SC 3	100	--	88	--	94	81	91	71	117	16	103	19	120	78	106	10	104	72	115	85
SC 4	374	334	268	255	276	237	260	232	185	137	180	132	205	128	146	72	141	103	122	94



Range of Orthophosphorus in GAPs
Summer of 1996
ppb
1200
1000
800
600
400
200
0
June
July
Aug
Average of all GAPs

Table 4. Iron to Phosphorus Ratios in mg/l

Site:	Fe:P	Fe:P
#1a	24:1	43:1
#1b	17:1	14:1
#2a	11:1	9:1
#2b	20:1	17:1
#3a	95:1	86:1
#3b	77:1	65:1
#4a	10:1	13:1
#4b	11:1	17:1
#5a	16:1	20:1
#5b	89:1	108:1
SC3	.8:1	.9:1
SC4	2:1	2:1
Muskrat	.3:1	.4:1

Table 5. Specific Conductance and Temperature of GAPs and Surface Waters

Site:	Conductivity in umhos/cm2 In	Out	Temperature in degrees Celsius In
#1a	1300	700	
#1b	1350	700	
Average	1325	700	
#2a	900	450	
#2b	950	450	
Average	925	450	
#3a	1800	1000	17
#3b	1800	1000	17.5
Average	1800	1000	
#4a	1050	1020	15
#4b	650	1020	12
Average			
#5a	1000	420	12
#5b	1100	420	14
Average	1050	420	
SC4	500		24
SC3	550		24
PR6	320		24
Sallie	405		24
Muskrat	370		24

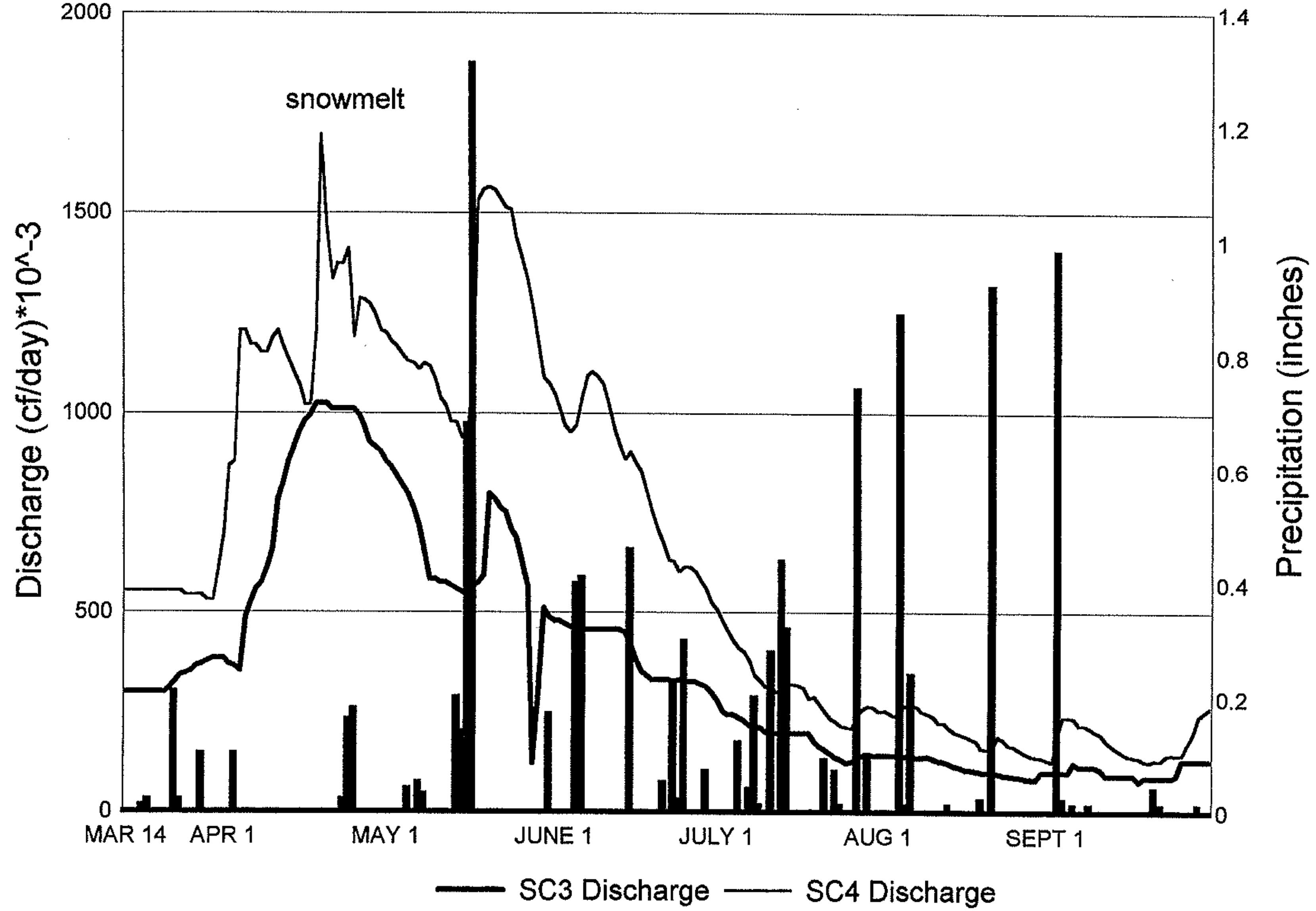
Lake Sallie watershed wetland soil test results for June, 1996.

		N	Phosphorus		K	Zn	S	Fe	Cu	Mn	B	Org Mat	pH	Ca	Mg	Na	CEC
			Bray	Olsen													
		lbs/ac	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%		ppm	ppm	ppm	meq/100g
RR1	1a.	4	4	15	23	2.0	16	166	0.48	18	1.7	46	7.6	4200	525	57	26
RR2	1b.	3	3	12 ~~10~~	19	0.2	24	166	0.36	19	2.0	47	7.9	4400	590	64	27
Nest 3	2a.	2	9	9	14	0.2	26	182	0.32	13	1.9	54	7.4	2560	535	71	18
Nest 4	2b.	4	4	12	15	0.3	28	172	0.38	19	1.5	61	7.2	4720	717	66	30
SC 3a-5	3a.	3	6	13	26	0.8	33	186	0.64	20	3.1	40	7.2	1760	920	103	17
SC 3a-6	3b.	3	13	18 –	31	1.1	29	186	0.58	21	4.1	43	6.8	1720	865	89	16
SC 3a-6-shells		6	2	7	56	1.0	123	150	1.70	24	1.6	17	7.8	2300	792	90	23
Putt 7	4a	2	6	10	14	1.6	23	134	0.24	13	2.0	32	6.8	1520	865	99	15
Putt 8	4b	1	5	8	20	0.5	13	110	0.24	6	1.5	63	6.8	320	437	49	6
Dog 9	5a	2	5	13	17	1.8	17	184	0.44	15	3.5	45	6.7	2080	630	32	16
Dog 10	5b	3	6	11	11	1.3	18	162	0.32	11	2.4	55	6.8	2320	675	23	17

- Soils are variable
- Soils do not have exceptionally high P; P may be coming in from outside the wetland?

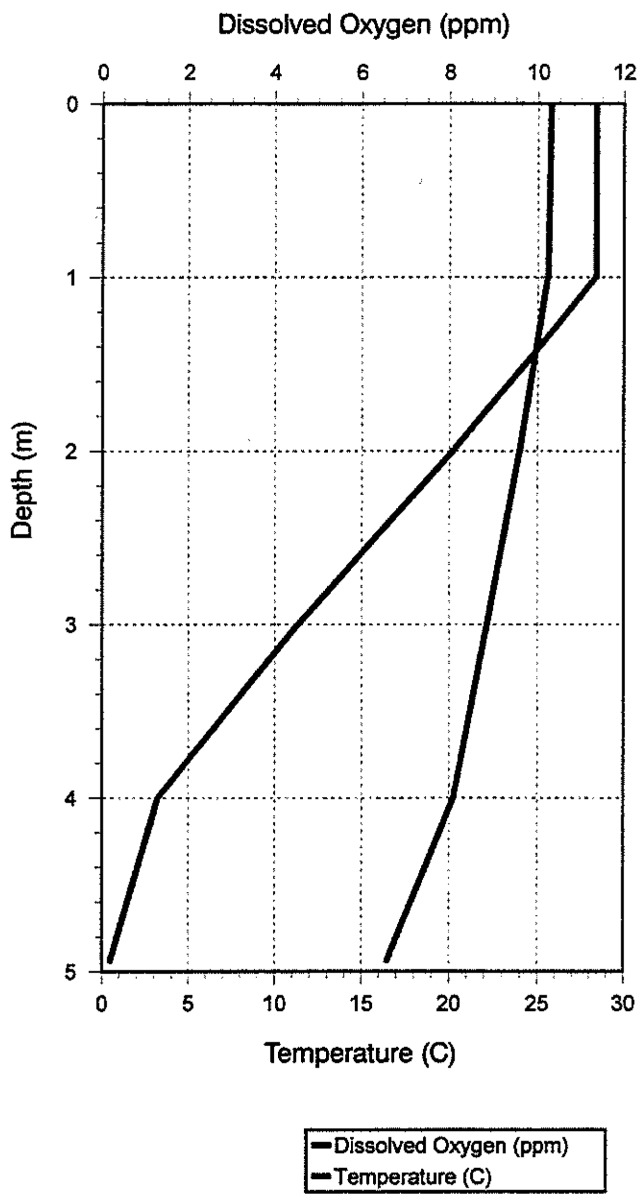
if pH 7.5+
olsen is our assay

SC3 and SC4 Discharges, Precipitation
from March 14 to September 30, 1996



Appendix C

Muskrat Lake and Lake St. Clair Background Information



Muskrat Lake
July 17, 1996
(secchi disc: 6.5 ft)

Muskrat

Boat Electrofishing Catch Summary

No data reported in ELECTROF.DBF

Historical Electrofishing Catch Summary

There are no pre-93 electrofishing data.

There are no data for length-frequency distribution.

Discussion

Muskrat Lake is a relatively small (67 acre), shallow (18' max. depth), fertile (0.064 ppm total phosphorus) lake on the Pelican River chain of lakes and located between lakes Detroit and Sallie. A dam (formerly a lock and dam system) on it's outlet to Lake Sallie, built in the early part of this century, maintains the water level in both Detroit and Muskrat lakes and is a migration barrier for fish attempting to swim upstream from Lake Sallie. Fertility is probably due mainly to cultural eutrophication from the City of Detroit Lakes, though changes in the sewage treatment plant have reportedly improved conditions in downstream lakes.

The lake is classified by Becker County as a "recreational development" lake and there is light shoreline development on the southeast shore. Much of the north and west shores of the lake are included in Dunton Locks County Park. This land, while not subject to home construction, contains a boat tramway to Lake Sallie, several picnic shelters and tables, a fishing dock, and hiking and cross country ski trails.

Muskrat Lake's physical and chemical characteristics make it subject to algal blooms, dense vegetation growth, and partial winterkill. Mid-summer angling is made difficult by those conditions, but spring and early summer shoreline angling is popular in the county park. The fish community composition is not unusual for similar lakes (class 39) with predators dominated by northern pike and invertebrate feeders dominated by bluegill and black bullhead.

The size of the lake precludes setting more than two gillnets and catch data for target species including northern pike and yellow perch are not statistically reliable for comparison. For instance, even though the gillnet catch for northern pike decreased from 14.5/GN in 1988 to 5.0/GN in 1993, one cannot say with confidence that there was a true decrease in the pike population. However, there is evidence from larger adjacent lakes that this may be the case.

Sampled total lengths of Muskrat Lake's northern pike ranged from 16 to 27 inches. Mean size of those pike was 21.3 inches TL weighing 2.1 pounds. Growth rates are normal.

Yellow perch numbers have decreased significantly during recent years. At 4.0/GN, they are lower than the first quartile for class 39 lakes. As abundance has decreased, average size has increased. Mean weight of sampled perch was 0.2 pounds and mean length was 7.7 inches with a range of lengths from six to nine inches. The growth rate is considered normal.

The black crappie population has remained unusually stable since original trapnetting in 1966. The catch rate (1.5/TN) is within the interquartile range for similar lakes. Black crappie are a popular target of shore anglers in spring. Although mean size of captured fish is not large, 8.5" TL weighing 0.4 lb., crappie up to 10"

TL were netted and, in some past years, fish weighing over two pounds were caught by anglers in early spring. Those large crappie were seemingly overfished in 1983 and 1984 and have apparently not been caught in significant numbers since then. They were thought by some to be migrants from Detroit Lake in search of early spring food in rapidly warming Muskrat Lake.

At 33.8/TN, bluegills remain in higher than normal abundance when compared to other class 39 lakes. Yet, numbers have declined significantly since 1988. Intra-specific competition undoubtedly accounts for slow growth rates for this species. Mean total length of a sample of 217 bluegills was 6.3 inches while mean weight was 0.2 pounds. Fish up to eight inches TL were captured but rare.

All three species of bullhead are present but black bullheads are most abundant. Black bullheads have significantly increased in number since 1988 and, at 20.4/TN, are more abundant now than at any time since test netting began in 1966. They are not overly grubby, yet probably small for ready marketability or angler acceptance. Mean length of netted fish was 8.3 inches and mean weight was 0.3 pounds.

Other fish species captured in test nets included bowfin, hybrid and pumpkinseed sunfishes, and largemouth bass. Pumpkinseeds seem to have decreased while hybrid sunfish have increased in recent years. Due to low vulnerability to standard survey nets, largemouth bass are not easily analyzed but abundance does not appear to have changed significantly.

Status of the Fishery

Muskrat Lake is a relatively small, shallow, fertile lake on the Pelican River chain of lakes, located between lakes Detroit and Sallie. It's outlet dam to Lake Sallie, built in the early part of this century, maintains water levels in both Detroit and Muskrat lakes and is a migration barrier for fish attempting to swim upstream from Lake Sallie. Fertility is probably due mainly to cultural eutrophication from the City of Detroit Lakes, though changes in the sewage treatment plant have reportedly improved conditions in downstream lakes, including Muskrat.

There is light shoreline development on the southeast shore. Much of the north and west shores of the lake are included in Dunton Locks County Park. This land, while not subject to home construction, contains a boat tramway to Lake Sallie, several picnic shelters and tables, a fishing dock, and hiking and cross country ski trails.

Muskrat Lake's physical and chemical characteristics make it subject to algal blooms, dense vegetation growth, and partial winterkill. Mid-summer angling is made difficult by those conditions, but spring and early summer shoreline angling is popular in the county park. The fish community composition is not unusual for similar lakes with northern pike, bluegill, and black bullhead dominating the fish community.

Muskrat Lake's northern pike ranged from 16 to 27 inches in length with the average pike 21 inches long weighing just over two pounds. Yellow perch are the preferred prey of pike in Muskrat Lake. Their numbers are currently low and seem to be decreasing but they are slightly larger than in the past, ranging from six to nine inches long. The black crappie population has remained unusually stable since original trapnetting in 1966. The catch rate is normal for similar lakes. Black crappie are a popular target of shore anglers in spring. Although fish captured in nets were not exceptionally large, the average was about 8.5 inches long weighing nearly one half pound, larger crappies are present. Bluegills have been considered overabundant and stunted since netting began in 1966, though some fish up to eight inches long were captured.

Bullheads are also abundant, expected in this type of lake. All three species of bullhead are present but black bullheads are most abundant. Mean length of netted black bullheads was 8.3 inches and mean weight was 0.3

pounds.

Other fish species captured in test nets included bowfin, hybrid and pumpkinseed sunfishes, and largemouth bass. Pumpkinseeds seem to have decreased while hybrid sunfish have increased in recent years. Due to low vulnerability to standard survey nets, largemouth bass are not easily analyzed but abundance does not appear to have changed significantly.

Paul D. [signature] September 17, 199

Area Fisheries Supervisor Date

Robert [signature] 12/4/94

Regional Fisheries Manager Date

entered 9/19/86 DP

MINNESOTA DEPARTMENT OF NATURAL RESOURCES
Division of Fish and Wildlife
LAKE SURVEY SUMMARY

1-03 Muskrat

GF-8 Rev. 8/75

Name Muskrat / At or Near Detroit Lakes	County(ies) Becker	Watershed No. 8	Ident. No. 3-360
Township(s) 138N	Range(s) 41W	Section(s) 8,9	Type of Lake Fish
Wetlands Classification V	Ecological Classification Centrarchid	Management Classification Centrarchid (Largemouth)	

SOURCE OF INFORMATION: 1. Fish Lake Survey Report 8/4-5/83 2. Game Lake Survey Report
3. Lake File 4. Gazetteer 5. D.O.W. Bulletin No. 25 6. 7.
Maps: 8. 3/28/67 9. 10.

Item	Data		Source
Area-Acres	66.5		8
D.O.W. Area-Acres	65		5
Max. Depth-Ft.	18		1
Median Depth-Ft.	7.5		8
Littoral Area-%	96		8
Shore Length-Mi.	2.0		8
Greatest Length-Mi.	0.6		8
Meandered-Yes or No	No		5
Annual Fluctuation-Ft.	+ .5 - 1.5		1
Long-term Fluctuation-Feet	+ 1.5 - 2.0		1
No. Islands	1		1
No. Dwellings	3		1
No. Resorts, Units at Resorts	0	0	1
No. Boats - Resort, Private	0	3	1
No. Boat Liveries	0		1

Dams: Two concrete "C" Type state owned 4 ft. head

Major Drainage Basin: Hudson Bay

Sequence of Waterways to Major Drainage Basin: Channel to Lake Sallie to Melissa to Buck to Little Pelican to Big Pelican to chain of lakes to Red River

	Trib. No. / Name	Location	Flow - C.F.S.	Source of Information
Inlets	Pelican R.	138-41-9	92	1
Outlet	Pelican R.	138-41-8	91	1

Watershed Description: low rolling farmland with scattered hardwoods

Watershed Ownership: 98% private 2% state and county

Benchmark: water level 4.4 feet below top center of west end of bridge at inlet

	Ledge-rock	Boulder	Rubble	Gravel	Sand	Silt	Clay	Muck				Source
Shoal Water Soils - %				30	30	20	20					1
Lake Bottom - %												

Shore Cover: 75% hardwood forest 25% grassland and marsh

Accessibility: county park on NW side Pelican R. from Detroit

Erosion & Pollution: winter discharge of treated sewage from city of Detroit Lakes

% Emergent Cover 3 Dist. cattails and sedge on east end - rest scattered

% Occur. Submerged Veg. Dist. abundant around entire lake

Water Plants - Species	Abund.	Water Plants - Species	Abund.	Water Plants - Species	Abund.
Sedge	O	Canada waterweed	O		
Common cattail	O	Yellow waterlily	R		
Arrowhead	R	Sago pondweed	P		
Coontail	A	Claspingleaf pondweed	R		
Lessor duckweed	A	Flatstem pondweed	R		
Star duckweed	A				
Water milfoil	A				

Algae: heavy growth of filamentous and blue green

Plants grew to depth of 9 Ft.

Fish Species	Abund. No.	Abund. Wt.	Gear	Growth Rate	Spawning Facilities	S.
Largemouth bass	0.60	0.96	T	Good	Excellent	1
Northern pike	21.5	42.2	G	Good	Fair	1
Bluegill	78.2	10.8	T	Slow	Excellent	1
Black crappie	2.0	0.54	T	Good	"	1
Pumpkinseed	3.6	0.52	T	Slow	"	1
Hybrid sunfish	0.8	0.20	T	Slow	"	1
Yellow perch	40	3.6	G			1
White sucker	2.5	5.0	G			1
Black bullhead	7.2	1.9	T			1
Brown bullhead	2.0	0.56	T			1
Yellow bullhead	3.4	1.4	T			1
Dogfish	1.2	5.5	T			1

Item	Surface	S.	Below Therm.	S.
Temp. - °F.	79.9	1	58.1	1
D.O. - p.p.m.	6.9	1	0.6	1
T.Alk. - p.p.m.	185	1		
SO_4 - p.p.m.	4.0	1		
Cl. - p.p.m.				
T.P. - p.p.m.	0.064	1		
T.N. - p.p.m.				
Color	brownish green			1
Secchi Disc Reading	7.0 Ft.			1
Cause of Turbidity	algae			1
Loc. of Therm.	6-12 Ft. from Surf.			1

Winterkill Dates 1977-78 1980-81 2 G. 5 T.

Special Problems: winter kills in years of low water flow in Pelican R. Extreme over nutrification from sewage discharge

ABBREVIATIONS: A - abundant, C - common, O - occasional, R - rare, P - present, S - source of data, G - 250' gillnet set for 24 hours, T - trapnet set for 24 hours, E - Electrofishing (hours).

Muskrat

WATERFOWL HABITAT						S.
Nesting Cover	Good					1
Brood Cover	Good					1
Loafing Areas	Good					1
Utilization - Species	No. Adults	No. Broods	Species	No. Adults	No. Broods	
Canada Geese	2	1				
Mallard	10	6				
Aquatic Furbearer Habitat	good mink, muskrat and beaver					1
Other Wildlife						

Recreational Use		Amount and/or Success	
Summer Angling	X	mainly in spring	1
Winter Angling	X		1
Spearing	X	fair success	1
Hunting			
Trapping	X	beaver, muskrat, mink	1
Ricing			
Boating			
Canoeing			
Waterskiing			
Picnicking			
Camping			
Swimming			

Management Recommendations: By__________ Date ________

Additional Information:

St. Clair

GF 165 Rev. 7-1-65

LAKE SURVEY SUMMARY

Name	County(ies)	Watershed No.	Ident. No.
Saint Clair At or Near: Detroit Lakes	Becker	VIII	3-382

Township(s)	Range(s)	Section(s)	Type of Lake
T.138-139 N.	R. 41 W.	S.4,5. 32, 33	Game - Mar. fish

Wetlands Classification	Ecological Classification	Management Classification
Type IV-Deep marsh	Waterfowl Aquatic furbearer -Mar. fish	Waterfowl -Aquatic furbearer

SOURCE OF INFORMATION: 1. Fish Lake Survey Report 2. Game Lake Survey Report 8-24-66
3. Lake File 4. Gazetteer 5. D.O.W. Bulletin No. 25 6. 7.
Maps: 8. 9. Field map 8/24/66 10.

Item	Data	Source
Area-Acres	140	9
D.O.W. Area-Acres	242	5
Max. Depth-Ft.	7.5	9
Median Depth-Ft.	4.5	9
Littoral Area-%	100%	9
Shore Length-Mi.	2.3 mi	9
Greatest Length-Mi.	7/8 mi	9
Meandered-Yes or No	Yes	5
Annual Fluctuation-Ft.	+0.5 0.5	2
Long-term Fluctuation-Feet	+1.0 , 1.0	2
No. Islands	0	-
No. Dwellings	0	-
No. Resorts, Units at Resorts	0 / 0	
No. Boats - Resort, Private	0 / 0	
No. Boat Liveries	0	

Dams: None.

Major Drainage Basin: Hudson Bay

Sequence of Waterways to Major Drainage Basin: C.D. #14 - Pelican River, Otter Tail River - Red River - Hudson Bay.

Inlets - Trib. No.	Location			Flow C.F.S.	Source of Information
C.D. 14	T.137	R. 41	S. 33	1.0	
C.D. 14	T.137	R. 41	S. 33	1.1	
Unnamed	T.137	R. 41	S. 32	4.5	2
Outlet: Unnamed	T.139	R. 41	S. 32	1.5	
C.D # 14	T.138	R. 41	S. 4	8.3	2

Watershed Description: Mixed hardwood forests and cropland over gently rolling sand loam hills.

Watershed Ownership: Private.

Benchmark: water level 4.0 feet below top of a metal tap on lake side of a long cottonwood standing near an improved access on south shore.

Shoal Water	Ledge-rock	Boulder	Rubble	Gravel	Sand	Silt	Clay	Muck	Detritus		muck/detritus	Source
Soils - %											100%	2
Lake Bottom - %								5	81		14	2

Shore Cover: Idle land -30%; marsh -30%; pasture -10%; crops -30%.

Accessibility: Public access on east shore of new highway # 59.

Erosion & Pollution: Affluent seepage from sewage settleing pond north of the lake.

% Emergent Cover: 25% Dist. Heavy typha stands around nearly all of the lake area.

% Occur. Submerged Veg.: 96% Dist. Much of the lake bottom supported a heavy vegetation growth.

Water Plants - Species	Abund.	Water Plants - Species	Abund.	Water Plants - Species	Abund.
Cattail	A	Wild rye	P	Sago pondweed	C
Hardstem bulrush	P	Arrowhead	P	Widgeon grass	P
Whitetop	P	Cane	P	Bluntleaf pondweed	P
Wild millet	P	Spikerush	P	Claspingleaf pondweed	P
Sedge	P	Needlerush	P	Greater duckweed	P
Cord grass	P	Coontail	A	Star duckweed	P
Cutgrass	P	Lesser duckweed	A	Watermilfoil	P

Algae: Filamentous algal growth along south western and south shore

Plants grew to depth of 7.5 Ft.

Fish Species	ABUND. No.	Wt.	Gear	Growth Rate	Spawning Facilities	S.

Item	Surface	S.	Below Therm.	S.
Temp. - °F.				
D.O. - p.p.m.				
T.Alk. - p.p.m.				
SO_4 - p.p.m.				
Cl. - p.p.m.				
T.P. - p.p.m.				
T.N. - p.p.m.				
Color	Brownish			2
Secchi Disc Reading Ft.	clear to bottom			2
Cause of Turbidity	Bog stain			2
Loc. of Therm.	Ft. from Surf.			

Winterkill Dates: Unknown. G. T. 2

Special Problems: See additional information.

ABBREVIATIONS: *A - abundant, C - common, O - occasional, R - rare, P - present, S - source of data,*
G - 250' gillnet set for 24 h...

St. Clair

						S.
WATERFOWL HABITAT	Excellent for both divers & puddlers.					
Nesting Cover	Excellent for both divers and puddlers.					2
Brood Cover	Excellent for both divers and puddlers					2
Loafing Areas	Floating sedge mats, trampled vegetation, excellent loafings.					2
Utilization - Species	No. Adults	No. Broods	Species	No. Adults	No. Broods	
Blue-winged teal	80 est.	—	Woodduck	25 est.	—	2
Mallard	30 est.	—	Coot	10 est.	—	2
Lesser scaup	20 est.	—	Grebe	4 est.	—	2
Aquatic Furbearer Habitat	The muskrat habitat was considered to be excellent with extensive areas of emergent vegetation for food and shelter.					2 2
Other Wildlife	The partially forested surrounding farmland provide a very good habitat for deer, raccoon, pheasant, fox, skunk, etc.					2 2

Recreational Use		Amount and/or Success	
Summer Angling			
Winter Angling			
Spearing			
Hunting	Yes	Light, duck hunting with good success.	2
Trapping	Yes	Light muskrat trapping with good success.	2
Ricing			
Boating			
Canoeing			
Waterskiing			
Picnicking			
Camping			
Swimming			

Management Recommendations: By__________ Date________

TXXXXXXX

Additional Information:

The lake was opened to promiscuous fishing in 1964. 290 Northern pike adults were rescued in 1956. In 1957 10,534 lbs. of northern pike were rescued. Also in that year 21,000 lbs. of bullheads were removed and destroyed. In 1962, 99 yearlings northered pipe were rescued.

Access to the lake is difficult because of the heavy floating band of emergents surrounding the lake.

St. Clair has a freeze-out histroy and fish rescue has been deemed necessary several times in recent history.

The lake is extremely fertile due to the seepage of affluents from the sewage settleing pond directly north of the lake.

St. Clair

175
8 1

entered on range card by M.F.G.

Copy of field survey mailed to Ward

OTHER SECTIONS

MINNESOTA DIVISION OF GAME AND FISH
SECTION OF RESEARCH AND PLANNING
FEDERAL AID PROJECT FW-1-R-11

Game LAKE SURVEY

DATES OF FIELD WORK
LAKE SURVEY 8-24-66
LAKE MAPPING 8-24-66

CREW LEADER Roger Engleson
ASSISTANT(S) Mike Eastvold

INTRODUCTION

LAKE NAME, IDENTIFICATION NUMBERS, MEANDER STATUS, AND LOCATION

LAKE NAME St. Clair ALTERNATE NAME (S)
LAKE IDENTIFICATION 3-382 MEANDERED Yes
LEGAL DESCRIPTION: T. 138-139 N. ; R. 41 W. ; S. 4,5,; 32,33
WATERSHED TRIBUTARY NUMBER AND NAME Otter Tail River Watershed # VIII
COUNTY (IES) Becker.
NEAREST INCORPORATED MUNICIPALITY, DISTANCE, AND DIRECTION The lake is 1 mile west of Detroit Lakes Minnesota.

ACCESSIBILITY

DESIGNATED PUBLIC ACCESS AREA (S) (LOCATE ON MAP) AND OWNERSHIP
The lake is accessible from an approach near the central east shore off from New Highway # 59.
OTHER ACCESS AREAS
An improved access is located across the road from a horse farm near the south east shore of the lake.

MANAGEMENT PROBLEM - REASON FOR SURVEY
An inventory of Fish and Wildlife Habitat of the Otter Tail River Watershed.

SURVEY REQUEST BY
Section of Technical Services, Division of Game and fish.

PREVIOUS INVESTIGATIONS AND SURVEYS AND DATES
None known.

LAKE AND DRAINAGE BASIN CHARACTERISTICS

LAKE AREA AND DEPTH:
AREA: MEANDERED ACREAGE 591.25
PLAINIMETERED ACREAGE - HIGHWATER 250 EXISTING 140
DEPTH IN FEET: MAXIMUM 7.5 MEDIAN 4.5
ABOUT 2 % OF WATER AREA IS LESS THAN 1 FOOT.
ABOUT 45 % OF WATER AREA IS LESS THAN 4 FEET.
DRAINAGE RATIO: INFORMATION SOURCE
MILES OF SHORELINE: HIGHWATER EXISTING

COUNTY (IES) ______________________

		INLETS* 1		2		3		4		5		OUTLET* 1	
	NAME	County Ditch 14		Co. Ditch 14		Unnamed		Unnamed				Co. Ditch 14	
	T., R., & S.	T.139; R.41; S. 33		T.139; R.41 S. 33		T.139; R.41; S. 32		T.139; R.41 S.32 ;				T.138; R. 41; S. 4	
	TYPE	8-24-66		8-24-66		8-24-66		8-26-66				8-24-66	
	LOCATION ON LAKE	North Bay		North Bay		Far west shore		Far north bay				Central east shore.	
	ORIGIN OF INLET(S)	Type III marsh directly west of Detroit Lakes		Unnamed and Mud Lake 2 miles north of lake.		Long Lake 1/3 mile west.		Detroit Lakes Sewage Disposal drain.				TRIBUTARY STATUS AND DISTANCE outle to Pelican River 1 mile southeast	
		AT FLOW STATION	WHOLE STREAM	AT FLOW STATION	WHOLE STREAM	AT FLOW STATION	WHOLE STREAM	AT FLOW STATION	WHOLE STREAM	AT FLOW STATION	WHOLE STREAM	AT FLOW STATION	WHOLE STREAM
SHOW ALL FLOW CALCULATION FIGURES ON REVERSE SIDE	AVERAGE WATER WIDTH-FEET	4.5'	10'	2.3'	8'	3.3'	5'					4'0"	10'
	AVERAGE WATER DEPTH-FEET	1.5'	1.5'	.7'	8"	0.5'	0.5'					2'3"	2'
	VELOCITY-FEET PER SECOND	1/6 f/s				3 f/s						1 f/s	
	DISTANCE OF FLOW MEASUREMENT-FEET	100'		40'		30'						160'	
	FLOW-C.F.S. IF DRY, SO INDICATE	1 c.f.s.		1.1 c.f.s.		4.5 c.f.s.		1.5 c.f.s.				8.3 c.f.s.	
THIS INFORMATION REQUIRED FOR DRY STREAMS ALSO	& BOTTOM TYPES ESP. SPAWNING AREAS+	silt, sand clay & gravel		silt, sand muck		sand & gravel						Mixed silt, sand clay & gravel.	
	BANK TYPES AND COVER	steep, grassy & emergent veg.		Gradual -grassy with emergents		gradual - grassy						Steep, grasses, occasional trees and brush.	
	BANK TOP HEIGHT-RANGE IN FEET ABOVE WATER SURFACE	2 feet to 10 feet.		3 feet to 6 feet.		2 feet to 5 feet.						3 ft. to 10 ft.	
	BANK TO BANK TOP DISTANCE, RANGE (FT.)	15 feet to 30 feet.		20' to 50'		8 feet to 15 feet.						15' to 30'	
	BARRIERS TO FISH MOVEMENT	None noted		None noted		None noted						None noted.	

OUTLET ELEVATION - CRITICAL BOTTOM ELEVATION - INDICATE (SHOW GAUGE READING OR MEASURE IN FEET AND/OR INCHES) ABOVE OR BELOW THE PRESENT LAKE WATER LEVEL: 6 inches below.

*ALSO INCLUDE AND INDICATE WHICH ARE DRY OR INTERMITTENT INLETS AND/OR OUTLET.
+SEE PAGE 5 OF GAME LAKE SURVEY MANUAL FOR BOTTOM DESCRIPTIONS.

St. Clair

St. Clair

LAKE St. Clair
COUNTY(IES) Becker

LAKE WATER LEVEL FLUCTUATIONS (DESCRIBE IN FEET ABOVE OR BELOW PRESENT LAKE LEVEL)
WITH REFERENCE TO NORMAL:
PRESENT STAGE OF LAKE + ½ foot.
ANNUAL FLUCTUATION OF LAST FEW YEARS ± ½ foot to ½ foot.
EXTREME (LONG-TERM) FLUCTUATION ± 1 foot to 1 feet.
ORDINARY SPRING HIGHWATER LINE + ½ foot.
HISTORY OF PAST WATER LEVEL FLUCTUATIONS Local residents report that the lake was done in the lake 30's.

LAKE WATER LEVEL CONTROLS None noted. DATE OBSERVED
DAMS (SKETCH AND GIVE MEASUREMENTS ON REVERSE SIDE)
GAUGE READING OF LAKE WATER LEVEL ______ FEET, HEAD ______ FEET, ELEVATION OF SILL WITH REFERENCE TO (INDICATE - SHOW GAUGE READING OR MEASURE IN FEET AND/OR INCHES - ABOVE OR BELOW THE PRESENT LAKE WATER LEVEL)
WATER FLOWAGE WIDTH OF DAM ______ FEET, DESCRIPTION OF DAM
LOCATION AND APPROXIMATE DISTANCE FROM LAKE
OWNERSHIP
OTHER STRUCTURES OR BARRIERS (SKETCH AND GIVE MEASUREMENTS ON REVERSE SIDE)
DESCRIPTION
LOCATION AND APPROXIMATE DISTANCE FROM LAKE

BENCHMARK AND LAKE WATER LEVEL DATE OBSERVED 8-24-66
WATER LEVEL 4.0 FEET BELOW BENCHMARK, DESCRIPTION AND LOCATION OF BENCHMARK Top of a metal tag on lake side of a lone cottonwood standing, near an improved access on south shore of lake.
DESCRIPTION AND LOCATION OF OTHER OR PREVIOUS BENCHMARKS = INDICATE WATER SURFACE ELEVATIONS AND DATES READ None known.

ELEVATION OF HIGHWATER LINE WITH REFERENCE TO WATER SURFACE + ½ foot.

NATURE AND USE OF LAKE'S IMMEDIATE WATERSHED
OTHER WATER AREAS WITHIN ONE MILE (OUTLINE ON MAP)

CLASS(II, III, IV, ETC.)	NUMBER	APPROXIMATE ACREAGE

TOPOGRAPHY OF SURROUNDING LAND AREA: Mixed hardwood forests and cropland over gently rolling sand loam hills.
ESTIMATED LAND USE (IN PERCENTAGE)

TYPE	IMMEDIATE	VICINITY

St. Clair

LAKE: St. Clair
COUNTY (IES): Becker

NATURE AND USE OF SHORELINE

ABOVE WATER SURFACE

SLOPE Gentle -70%; gradual -30%.

COVER Idle land -30%; marshland -30%; pasture -10%; crops -30%.

SOIL TYPE Mixed clay and sand loam.

BELOW WATER SURFACE

SLOPE Gentle -100%.

VEGETATION Dense aquatic vegetation along 90% of the shoreline.

SOIL TYPE Detritus over muck.

LOCATION OF SHORELINE DEVELOPMENT AREAS AROUND LAKE

None noted.

COUNTS OF SHORELINE DEVELOPMENTS

NUMBER OF RESORTS ______, NUMBER CABINS AT RESORTS ______, NUMBER OF HOMES AND/OR COTTAGES ______, NUMBER OF BOATS ______

III. EVIDENCE AND EXTENT OF EROSION AND/OR POLLUTION

Refer to special problems.

IV. PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER (LOCATE STATIONS ON MAP)

WATER TURBIDITY: TOTAL NUMBER OF SECCHI DISC READINGS Entire lake clear to bottom.

MAXIMUM 7.5' AVERAGE ______ MIN. ______

COLOR OF WATER Brownish COLOR CAUSE Bog Stain

TURBIDITY CAUSE ______

WEATHER 70° SKY Clear to PCL WIND 10-15 m.p.h.

BOTTOM SOIL TYPES

Much of the lake bottom consisted of detritus over a deep layer of muck.

TYPE	PERCENTAGE OCCURRENCE
Detritus	81%
Muck-Detritus	14%
Muck	5%

WATER QUALITY None taken.

FIELD TEST

TOTAL ALKALINITY: BURETTE READING

START	END	P.P.M.

LABORATORY TEST

	P.P.M.		P.P.M.
SULPHATE (SO_4) ION		AMMONIA NITROGEN (NH_3-N)	
TOTAL PHOSPHORUS (TOTAL P)		NITRITE NITROGEN (NO_2-N)	
CHLORIDE (CL) ION		NITRATE NITROGEN (NO_3-N)	
CARBON DIOXIDE (CO_2)		ORGANTIC NITROGEN (ORGANIC N)	
TOTAL ALKALINITY (TA)		TOTAL NITROGEN (TOTAL N)	

SUMMARY ______

St. Clair

LAKE St. Clair
COUNTY (IES) Becker

V. BIOLOGICAL CHARACTERISTICS OF LAKE

OBSERVATION DATE (PLANTS) 8-24-66

AQUATIC PLANTS (SEE PAGES 18 AND 19 - MANUAL OF INSTRUCTIONS FOR GAME LAKE SURVEYS)

SPECIES OF EMERGENT AQUATIC PLANTS

ABOUT 25 PERCENT OF THE PRESENT LAKE WATER AREA IS COVERED BY STANDING EMERGENT VEGETATION.

COMMON NAME	SCIENTIFIC NAME	*RELATIVE ABUNDANCE	DISTRIBUTION	**FOOD VALUE TO WATERFOWL
Cattail	Typha spp.	Abundant	General shoreline	—
Hardstem bulrush	Scirpus acutus	Present	"	G
Whitetop	Scolochloa festucacea	"	"	S
Wild millet	Echinochloa spp.	"	"	E
Sedge	Carex spp.	"	"	S F
Cord grass	Spartina pectinata	"	"	S F
Cut grass	Leersia oryzoides	"	"	F G
Wild rye	Elymus virginicus	"	"	—
Arrowhead	Sagittaria latifolia	"	"	F
Cane	Phragmites communis	"	"	—
Spikerush	Eleocharis palustris	"	"	F G
Needlerush	Eleocharis acicularis	"	"	F G

DESCRIPTION AND LOCATION OF EMERGENT PLANT DISTRIBUTION (OUTLINE EMERGENT PLANT AREAS ON MAP)
The emergent vegetation was composed mainly of cattail. Abundance ratings of the other emergents listed were unobtainable because they were blocked from view from the lake by the dense cattail stand.

*RELATIVE ABUNDANCE OF EACH SPECIES WHEN COMPARED TO TOTAL EMERGENT VEGETATION IN LAKE.
USE FOLLOWING DENSITIES: ABUNDANT, COMMON, OCCASIONAL, SCARCE.

SPECIES OF FLOATING-LEAVED AND SUBMERGED AQUATIC PLANTS

TOTAL % OCCURRENCE OF SUBMERGED VEGETATION 96%
GREATEST DEPTH TO WHICH ROOTED SUBMERGED PLANTS GROW 7.5 FEET.

COMMON NAME	SCIENTIFIC NAME	% OCCURRENCE N 27	DENSITY	DISTRIBUTION	**FOOD VALUE TO WATERFOWL
Coontail	Ceratophyllum demersum	88	Lush	General lake bottom	S F
Lesser duckweed	Lemna minor	44	Lush	Shallower areas	F E
Sago pondweed	Potamogeton pectinatus	28	Common	Shallower areas	E
Widgeon grass	Ruppia occidentalis	8	Lush	South shoreline	E
Bluntleaf pondweed	Potamogeton obtusifolius		Present	Scattered plants	—
Claspingleaf pondweed	Potamogeton Richardsonii		"	Scattered plants	G
Greater duckweed	Spirodela polyrhiza		"	Along shore	—
Star duckweed	Lemna trisulca		"	Along shore	F E
Water milfoil	Myriophyllum exalbescens		"	Scattered beds	S F
Flatstem pondweed	Potamogeton zosteriformis		"	Scattered plants	F

**S - SLIGHT; SF - SLIGHT-FAIR; F - FAIR; FG - FAIR-GOOD; FE - FAIR-EXCELLENT; G - GOOD; GE - GOOD-EXCELLENT;

LAKE St. Clair
COUNTY(IES) Becker

DESCRIPTION AND LOCATION OF SUBMERGED PLANT DISTRIBUTION Much of the shoal waters supported an supported an extremely heavy growth of coontail & lesser duckweed. Scattered areas in th deeper portions of the lake also had a very heavy growth. The sago pondweed and widgeon grass growth were mainly noted in the south half of the lake.

ALGAE: TYPE	FREQUENCY OCCURRENCE	DENSITY
Filamentous	30%	Lush

DISTRIBUTION NOTES
The filamentous algal growth was noted mainly along the south western and southern portions of the lake.

NOTES ON PLANKTON AND INSECTS: The lake appeared to have abundant water insect life, especiall in the areas covered with lesser duckweed.

WILDLIFE HABITAT AND UTILIZATION

WATERFOWL HABITAT - GENERAL DESCRIPTION
The lake is regarded as an excellent habitat for both puddlers and divers.

WATERFOWL NESTING COVER - TYPE, LOCATION, AND AMOUNT Scattered areas of idle land pasture, croplan much emergent vegetation and marsh land all provide excellent nesting cover.

WATERFOWL BROOD COVER - TYPE, LOCATION, AND AMOUNT Extensive areas of cattail growth provide excellent brood cover.

WATERFOWL LOAFING SITES - TYPE, LOCATION, AND AMOUNT Floating sedge mats, flooding mats, of trampled vegetation provide excellent loafing sites.

WATERFOWL UTILIZATION AT TIME OF SURVEY - OFFICIAL COUNT: DATE 8-24-66
TIME P. M. WEATHER: SKY Clear to PLC WIND 10-15 m.p.h.

SPECIES	ADULTS OFFICIAL COUNT	ADULTS SURVEY TOTAL	BROODS OFFICIAL COUNT	BROODS SURVEY TOTAL
Blue-winged teal	80 est.			
Mallard	30 est.			
Lesser scaup	20 est.			
Woodduck	25 est.			
Coot	10 est.			
Grebe	4			

AQUATIC FURBEARER HABITAT - GENERAL DESCRIPTION
The muskrat habitat was considered to be excellent with extensive areas of emergent vegetation for food and shelter.

AQUATIC FURBEARER UTILIZATION

SPECIES	TYPE OBSERVATION (CUTTINGS, HOUSES, ETC.)	EXTENT AND LOCATION
Muskrat	Numerous houses were noted especially near the north and east shores.	

LAKE St. Clair
COUNTY(IES) Becker

OTHER WILDLIFE (PHEASANTS, DEER, ETC.)

PRINCIPAL OTHER WILDLIFE SPECIES OF AREA Deer, raccoon, pheasant, fox, skunk, squirrel, rabbit, etc.

OTHER WILDLIFE HABITAT - GENERAL DESCRIPTION The partially forested surrounding farmland provide a very good habitat for the above named species.

OTHER WILDLIFE UTILIZATION

SPECIES	TYPE OBSERVATION (SIGHTING, TRACKS, ETC.)	EXTENT AND LOCATION

HISTORY OF WILDLIFE UTILIZATION AND HARVESTS

FROM PREVIOUS INVESTIGATIONS

None known.

FROM LOCAL REPORTS OR OTHER SOURCES

SOURCES OF INFORMATION

Local resident.

HISTORY OF UTILIZATION (PRODUCTION, MIGRATION, WINTERING, ETC.)

SPECIES OF WATERFOWL AND OTHER WILDLIFE	TYPE UTILIZATION	OTHER INFORMATION - EXTENT AND LOCATION OF UTILIZATION, ETC.
Puddlers	Migration & nesting	General lake area
Divers	Migration & nesting	General lake area

HISTORY OF HARVESTS

SPECIES OF WATERFOWL AND OTHER WILDLIFE	PRESSURE*	SUCCESS**	OTHER INFORMATION - AREAS OF LAKE HUNTED - TIME OF SEASON, ETC.
Puddlers	Light	Good	The general lake is hunted
Divers	Light	Good	lightly because of poor access.

*HEAVY, MODERATE, LIGHT **SUCCESS - GOOD, FAIR, POOR

NON-GAME WILDLIFE UTILIZATION (SHOREBIRDS, HERONS, ETC.) 4 great blue herons were sighted during survey as well as many gulls and terns.

HISTORY OF TRAPPING

PREDOMINANT SPECIES	PRESSURE	SUCCESS
Muskrat	Light	Good

LAKE St. Clair
COUNTY(IES) Becker

WILD RICE

LOCATION OF WILD RICE STANDS IF PRESENT (OUTLINE ON MAP)
None noted.

DENSITY AND CONDITION OF WILD RICE STANDS IF PRESENT

HISTORY OF WILD RICE HARVESTS

FISHERY

SPECIES PRESENT	RELATIVE ABUNDANCE (ABUNDANT, COMMON, ETC.)
Minnows	Common
Northern Pike	Unknown
Sunfish	Unknown

METHODS USED TO DETERMINE PRESENT OR ABSENCE (SEINING, SIGHTING, ETC.)
All fish were sighted during the survey.

EVIDENCE OF ROUGH FISH ACTION
None noted.

POSSIBILITIES OF ROUGH FISH CONTROL

VI. HISTORY OF FISHING

FROM PREVIOUS INVESTIGATIONS AND SURVEYS
The lake was opened to promiscuous fishing in 1964.

FROM LOCAL REPORTS AND PRESENT OBSERVATIONS

FISH MOST COMMONLY CAUGHT AND RECENT (THIS YEAR AND LAST SEASON) ANGLING SUCCESS

SPECIES OF FISH	ANGLING SUCCESS*	OTHER INFORMATION (SIZES, TIME OF YEAR, ETC.)

*GOOD, FAIR, POOR, ETC.

PAST ANGLING HISTORY

LAKE St. Clair
COUNTY(IES) Becker

VII. RECORD OF PAST MANAGEMENT

The lake was opened to promiscusus fishing in 1964. 290 Northern pike adults were rescued in 1956. In 1957 10,534 lbs. of Northern Pike were rescued. Also in that year 21,000 lbs. of bullheads were removed and destroyed. In 1962 99 yearlings Northern pike were rescued.

SPECIAL LAKE CONDITIONS OR PROBLEMS

A partially destroyed fish barrier is located at the outlet from Long Lake.

A sewage settleing pond is located a few yards north of St. Clair.

Access to the lake is difficult becatse of the wide semi-floating band of emergents around nearly all of the lake proper.

VIII. ECOLOGICAL CLASSIFICATION AND STATUS

ECOLOGICAL CLASSIFICATION

Waterfowl-Aquatic furbearer - Marginal fish/

MEANDER STATUS

The lake is meandered at 591.25 acres.

WETLAND CLASSIFICATION

Marginal (Game) type VA

IX. SUMMARY DISCUSSION AND ADDITIONAL NOTES

St. Clair lake is planimetered at 140 acres of water areas and 250 acres of high-water potential. It has a maximum depth of 7.5 feet with a median of 4.5 feet. The lake is fed by four major inlets feeding a combined water volume of 8 cubic feet per second at the time of the survey.

The lake is regarded as an excellent waterfowl habitat for both puddlers, and divers. It received light hunting pressure with good success. Access to the lake is difficult because of the heavy floating band of emergent surrounding the lake.

The lake is extremely fertile due to the seepage of the effluents from the seapage settleing pond directly north of the lake -- See attached sheet.

St. Clair
Becker

FIELD WORK BY
Roger Engleson
Mike Eastvold

LABORATORY WORK AND PRELIMINARY REPORT BY
Roger Engleson

CLASSIFICATION AND RECOMMENDATIONS BY
Don Reedstrom

FEDERAL AID PROJECT

FW - 1 - R-11

APPROVED BY ~~/s/ Oliver~~ M. Jarvenpa
Supervisor of Technical Services

DATE 4/11/68

GF 175

MANAGEMENT RECOMMENDATIONS

St. Clair - Becker Co.
T.138; 139N; R. 41 W; S. 4,5,; 32, 33

DATES OF FIELD WORK
8-24-66

MANAGEMENT CLASSIFICATION
Waterfowl - Aquatic furbearer

RECOMMENDED MANAGEMENT

MAJOR MANAGEMENT (IF ADDITIONAL SPACE IS NEEDED EXPLAIN UNDER OTHER MANAGEMENT)

1. PUBLIC ACQUISITION OF AREA Public access should be acquired to this lake.
2. ACCESS ACQUISITION
3. WATER LEVEL MANIPULATION
4. FISHERIES MANAGEMENT
5. MANAGEMENT FOR RECREATIONAL USES OTHER THAN WILDLIFE AND FISHING

OTHER MANAGEMENT

SUBMITTED BY Don Reedstrom

DATE 4/13/67

Appendix D

BATHTUB and FLUX Runs for 1995 and 1996

247ac/KM2

12 months

CASE: 1996 Lake Sallie run [no internal loading]

HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	DISPERSION ESTIMATED KM2/YR	DISPERSION NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	34.60	.69942	7.1	4.8	256.	8.	0.

CASE: Lake Sallie, 1996

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1	1	PR6	162.000	27.620	.191E+01	.050	.170
2	1	SC4	~~2.690~~ 20.	8.190	.168E+00	.050	3.045
3	1	Septic Tanks	.000	.000	.000E+00	.000	.000
5	1	PR7	~~.000~~ 3.4	.000	.000E+00	.000	.000
6	4	PR8 - Outlet	.000	35.700	.000E+00	.000	.000
PRECIPITATION			4.840	2.420	.234E+00	.200	.500
TRIBUTARY INFLOW			823.450	35.810	.207E+01	.040	.043
***TOTAL INFLOW			828.290	38.230	.231E+01	.040	.046
GAUGED OUTFLOW			.000	35.700	.000E+00	.000	.000
ADVECTIVE OUTFLOW			828.290	-1.100	.350E+01	1.700	-.001
***TOTAL OUTFLOW			828.290	34.600	.350E+01	.054	.042
***EVAPORATION			.000	3.630	.119E+01	.300	.000

6.7 in; high; 1.7 inch; SC3 4.43; storage increase -1.646

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	PR6	690.5	29.6	.168E+04	11.3	.059	25.0	4.3
2	1	SC4	1523.3	65.2	.951E+04	64.0	.064	186.0	566.3
3	1	Septic Tanks	.0	.0	.000E+00	.0	.000	.0	.0
5	1	PR7	.0	.0	.000E+00	.0	.000	53.0	.0
6	4	PR8 - Outlet	1125.7	48.2	.722E+05	485.9	.239	31.5	.0
PRECIPITATION			121.0	5.2	.366E+04	24.6	.500	50.0	25.0
TRIBUTARY INFLOW			2213.8	94.8	.112E+05	75.4	.048	61.8	2.7
***TOTAL INFLOW			2334.8	100.0	.149E+05	100.0	.052	61.1	2.8
GAUGED OUTFLOW			1125.7	48.2	.722E+05	485.9	.239	31.5	.0
ADVECTIVE OUTFLOW			-34.7	-1.5	.358E+04	24.1	1.726	31.5	.0
***TOTAL OUTFLOW			1091.0	46.7	.696E+05	468.7	.242	31.5	1.3
***RETENTION			1243.9	53.3	.723E+05	486.9	.216	.0	.0

SC3 315; .035; 167

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
7.15	.6994	31.0	.3213	3.1123	.5327

CASE: 1996 Lake Sallie run

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Lake Sallie

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	31.0	.25	31.5	.24	.98	-.07	-.06	-.05
CHL-A	MG/M3	17.2	.00	14.5	.50	1.18	.00	.49	.34
SECCHI	M	2.6	.10	2.9	.36	.90	-1.10	-.39	-.30
ORGANIC N	MG/M3	.0	.00	497.8	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	24.8	.55	.00	.00	.00	.00

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Lake Sallie

VARIABLE	VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P MG/M3	31.00	31.53	31.4	32.1
CHL-A MG/M3	17.20	14.53	78.4	71.5
SECCHI M	2.60	2.90	87.6	90.3
ORGANIC N MG/M3	.00	497.78	.0	53.8
TP-ORTHO-P MG/M3	.00	24.76	.0	42.0
ANTILOG PC-1	181.90	139.87	41.0	33.4
ANTILOG PC-2	19.42	18.89	98.2	98.0
TURBIDITY 1/M	.13	.13	3.7	3.7
ZMIX * TURBIDITY	.58	.58	1.5	1.5
ZMIX / SECCHI	1.76	1.58	4.4	2.9
CHL-A * SECCHI	44.72	42.17	98.2	97.8
CHL-A / TOTAL P	.55	.46	94.9	91.1
FREQ(CHL-a>10) %	71.39	61.51	.0	.0
FREQ(CHL-a>20) %	29.00	20.45	.0	.0
FREQ(CHL-a>30) %	11.36	6.95	.0	.0
FREQ(CHL-a>40) %	4.73	2.60	.0	.0
FREQ(CHL-a>50) %	2.11	1.06	.0	.0
FREQ(CHL-a>60) %	1.00	.47	.0	.0
CARLSON TSI-P	53.67	53.91	.0	.0
CARLSON TSI-CHLA	58.51	56.85	.0	.0
CARLSON TSI-SEC	46.23	44.65	.0	.0

SEGMENT NETWORK: FLOWS IN HM3/YR

*************** SEGMENT:	1 Lake Sallie	INFLOW	OUTFLOW	EXCHANGE
PRECIP AND EVAPORATION:		2.42	3.63	
EXTERNAL INFLOW:	1 PR6	27.62		
EXTERNAL INFLOW:	2 SC4	8.19		
EXTERNAL INFLOW:	3 Septic Tanks	.00		
EXTERNAL INFLOW:	5 PR7	.00		
OUTFLOW / WITHDRAWAL:	6 PR8 - Outlet		35.70	
DISCHARGE OUT OF SYSTEM:			-1.10	

12 months

CASE: Revised 1995 Lake Sallie run

HYDRAULIC AND DISPERSION PARAMETERS:

SEG	OUT	NET INFLOW HM3/YR	RESIDENCE TIME YRS	OVERFLOW RATE M/YR	MEAN VELOCITY KM/YR	DISPERSION ESTIMATED KM2/YR	DISPERSION NUMERIC KM2/YR	EXCHANGE RATE HM3/YR
1	0	25.24	.95887	5.2	3.5	187.	6.	0.

CASE: Revised 95 Sallie run

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR	
1	1	PR6	162.000	19.000	.000E+00	.000	.117	4.6 in
2	1	SC4	20 ~~2.690~~	6.480	.000E+00	.000	~~2.409~~	.324
3	1	Septic Tanks	.000	.000	.000E+00	.000	.000	
5	1	PR7	3.4 ~~.000~~	.000	.000E+00	.000	.000	
6	4	PR8-Outlet	.000	25.250	.000E+00	.000	.000	
		PRECIPITATION	4.840	3.388	.459E+00	.200	.700	
		TRIBUTARY INFLOW	329.380	25.480	.000E+00	.000	.077	3.0 inch
		***TOTAL INFLOW	334.220	28.868	.459E+00	.023	.086	
		GAUGED OUTFLOW	.000	25.250	.000E+00	.000	.000	
		ADVECTIVE OUTFLOW	334.220	-.012	.165E+01	9.990	.000	
		***TOTAL OUTFLOW	334.220	25.238	.165E+01	.051	.076	
		***EVAPORATION	.000	3.630	.119E+01	.300	.000	

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	PR6	342.0	6.9	.421E+03	.1	.060	18.0	2.1
2	1	SC4	972.0	19.6	.945E+04	1.2	.100	150.0	361.3
3	1	Septic Tanks	.0	.0	.000E+00	.0	.000	.0	.0
5	1	PR7	.0	.0	.000E+00	.0	.000	37.0	.0
6	4	PR8-Outlet	1445.2	29.1	.227E+06	28.6	.330	57.2	.0
		PRECIPITATION	121.0	2.4	.366E+04	.5	.500	35.7	25.0
		INTERNAL LOAD	3535.6	71.1	.781E+06	98.3	.250	.0	.0
		TRIBUTARY INFLOW	1314.0	26.4	.987E+04	1.2	.076	51.6	4.0
		***TOTAL INFLOW	4970.6	100.0	.795E+06	100.0	.179	172.2	14.9
		GAUGED OUTFLOW	1445.2	29.1	.227E+06	28.6	.330	57.2	.0
		ADVECTIVE OUTFLOW	-.7	.0	.540E+04	.7	9.999	57.2	.0
		***TOTAL OUTFLOW	1444.5	29.1	.229E+06	28.8	.331	57.2	4.3
		***RETENTION	3526.1	70.9	.757E+06	95.2	.247	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
5.21	.9589	55.0	.2678	3.7345	.7094

CASE: Revised 1995 Lake Sallie Run

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Lake Sallie

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	55.0	.25	57.2	.33	.96	-.16	-.15	-.10
CHL-A	MG/M3	.0	.00	16.0	.42	.00	.00	.00	.00
SECCHI	M	2.0	.10	.8	.27	2.50	9.14	3.27	3.14

OBSERVED AND PREDICTED DIAGNOSTIC VARIABLES
RANKED AGAINST CE MODEL DEVELOPMENT DATA SET

SEGMENT: 1 Lake Sallie

VARIABLE		VALUES OBSERVED	VALUES ESTIMATED	RANKS (%) OBSERVED	RANKS (%) ESTIMATED
TOTAL P	MG/M3	55.00	57.23	56.1	57.8
CHL-A	MG/M3	.00	16.03	.0	75.6
SECCHI	M	2.05	.82	80.0	35.9
ANTILOG PC-1		.00	497.78	.0	70.6
ANTILOG PC-2		.00	7.55	.0	62.0
ZMIX / SECCHI		2.23	5.58	9.6	60.6
CHL-A * SECCHI		.00	13.16	.0	64.1
CHL-A / TOTAL P		.00	.28	.0	71.3
FREQ(CHL-a>10) %		.00	67.39	.0	.0
FREQ(CHL-a>20) %		.00	25.23	.0	.0
FREQ(CHL-a>30) %		.00	9.32	.0	.0
FREQ(CHL-a>40) %		.00	3.71	.0	.0
FREQ(CHL-a>50) %		.00	1.60	.0	.0
FREQ(CHL-a>60) %		.00	.74	.0	.0
CARLSON TSI-P		61.94	62.51	.0	.0
CARLSON TSI-CHLA		.00	57.81	.0	.0
CARLSON TSI-SEC		49.66	62.83	.0	.0

SEGMENT NETWORK: FLOWS IN HM3/YR

*************** SEGMENT:	1 Lake Sallie	INFLOW	OUTFLOW	EXCHANGE
PRECIP AND EVAPORATION:		3.39	3.63	
EXTERNAL INFLOW:	1 PR6	19.00		
EXTERNAL INFLOW:	2 SC4	6.48		
EXTERNAL INFLOW:	3 Septic Tanks	.00		
EXTERNAL INFLOW:	5 PR7	.00		
OUTFLOW / WITHDRAWAL:	6 PR8-Outlet		25.25	
DISCHARGE OUT OF SYSTEM:			-.01	

```
*******************************************************************
*              WISCONSIN LAKE MODEL SPREADSHEET                   *
*                 VERSION 1.01 - JULY 1994                        *
*          WISCONSIN DEPARTMENT OF NATURAL RESOURCES              *
* Although this model has been tested by WDNR, no warranty is     *
* expressed or implied.  See users manual prior to using model.   *
*******************************************************************
* LAKE ID     Sallie                                              *
* TO AUTO LOAD WTRSHD.   DATA ENTER COUNTY ID, HOLD ALT & TYPE  L *
* WATERSHED COUNTY IDENT. NUMBER   =        0 CO. NAME:       0   *
*******************************************************************
*             HYDROLOGIC AND MORPHOMETRIC MODULE                  *
* ============================================================== *
*                          ENGLISH          METRIC                *
* TRIB. DRAINAGE AREA    =  58378.0 Ac.      2.36E+08 m^2         *
* TOTAL UNIT RUNOFF      =      3.0 In.         0.076 m           *
* ANNUAL RUNOFF VOLUME   =  14594.5 Ac-Ft.   1.80E+07 m^3         *
* LAKE SURFACE AREA <As> =   1211.0 Ac.      4.90E+06 m^2         *
* L. VOLUME <V>          =  20587.0 Ac-ft.   2.54E+07 m^3         *
* L. MEAN DEPTH <z>      =    17.00 Ft.          5.18 m           *
* L. NET ANNUAL PRECIP.  =        0 In.          0.00 m           *
* HYDRAULIC LOADING      =  14594.5 Ac-Ft/Yr 1.80E+07 m^3/Yr      *
* AREAL WATER LOAD <qs>  = 1.21E+01 Ft/Yr.   3.67E+00 m/Yr        *
* L. FLUSHING RATE <p>   =     0.71 /Yr  Tw =    1.41 Yr          *
*******************************************************************
*                  PHOSPHORUS LOADING MODULE                      *
* ============================================================== *
*                           --LOADING (Kg/Ha-Yr)--                *
* LAND USE              AREA            MOST            LOADING   *
*                       (Ac)      LOW   LIKELY    HIGH  PERCENT   *
* AGRICULTURE            0.0     0.30     0.50    2.00     0.0    *
* FOREST                 0.0     0.05     0.10    0.20     0.0    *
* URBAN                  0.0     0.50     1.00    1.50     0.0    *
* OPEN GRASSLAND         0.0     0.10     0.30    0.50     0.0    *
* WETLAND                0.0     0.10     0.10    0.10     0.0    *
* PRECIPITATION       1211.0     0.10     0.30    1.00     2.9    *
* -------------------------------------------------------------- *
* POINT SOURCE WATER LOADING (m^3/Yr)          0.00E+00           *
* POINT SOURCE PHOS.(Kg/Yr) 4971.00  4971.00  4971.00     97.1    *
* SEP.TANK OUTPUT(kg/cp-yr)    0.70     0.80     2.10     ----    *
* # capita-years        0.00   ----    -----     ----     ----    *
* % P. RETAINED BY SOIL          98       90       80     ----    *
* SEP. TANK LOADING (Kg/Yr)    0.00     0.00     0.00      0.0    *
* -------------------------------------------------------------- *
* TOTAL LOADINGS (Lb)      1.11E+04 1.13E+04 1.20E+04    100.0    *
* TOTAL LOADINGS (Kg)      5.02E+03 5.12E+03 5.46E+03    100.0    *
* -------------------------------------------------------------  *
* AREAL LOADING(Lb/Ac-Yr) =9.14E+00 9.32E+00 9.94E+00             *
* AREAL LOADING(mg/m^2-yr)=1.02E+03 1.04E+03 1.11E+03             *
*   %  TOTAL PHOSPHORUS REDUCTION =        0                      *
*******************************************************************
```

```
****************************************************************
*                    PHOSPHORUS PREDICTION MODULE               *
* ============================================================= *
* OBSERVED SPRING TOTAL PHOSPHORUS          =     51    mg/m^3  *
* ------------------------------------------------------------- *
*                                                               *
*   LAKE PHOSPHORUS MODELS                         PREDICTED    *
*                                             TOTAL PHOSPHORUS  *
*                                                  (mg/m^3)     *
*                                             ----------------  *
* 1. WALKER, 1987  RESERVOIR MODEL                              *
*              64        65        69                   65      *
* 2. CANFIELD-BACHMANN, 1981, NATURAL LAKE MODEL                *
*                                                      101      *
* 3. CANFIELD-BACHMANN, 1981, ARTIFICAL LAKE MODEL              *
*                                                       67      *
* 4. RECKHOW, 1979, NATURAL LAKE MODEL                          *
*           0.064     0.065     0.070                   65      *
* 5. RECKHOW, 1977, ANOXIC LAKE MODEL                           *
*             204       208       221                  208      *
* 6. RECKHOW, 1977 OXIC LAKES   qs < 50 m/yr                    *
*             105       108       115                  108      *
* 7. RECKHOW, 1977 OXIC LAKES   qs > 50 m/yr                    *
*              56        57        61                   57      *
* 8. WALKER 1977, GENERAL LAKE MODEL                            *
*             143       143       143                  143      *
* 9. VOLLENWEIDER, 1975  LAKE MODEL                             *
*                                                       76      *
* 10. DILLON-RIGLER-KIRCHNER, 1975 LAKE MODEL                   *
*       P. RETENTION  COEFFICIENT <R>    0.71           82      *
****************************************************************
*                 UNCERTAINTY ANALYSIS MODULE                   *
* ============================================================= *
*                                                               *
*                           PREDICTED                           *
*                           MINUS                70 PERCENT     *
* LAKE RESPONSE MODEL       OBSERVED   PERCENT   CONFIDENCE     *
*                           (mg/m^3)   DIFF.     LIMITS(mg/m^3) *
* ------------------------------------------------------------- *
* 1.WALKER, 1987 RESERVOIR      14       27       47      89    *
* 2.CANFIELD-BACHMANN, 1981     50       98       31     291 <= *
* 3.CANFIELD-BACHMANN, 1981     16       31       21     194 <= *
* 4.RECKHOW, 1979 GENERAL       14       27       19      93    *
* 5.RECKHOW, 1977 ANOXIC       157      308      208     277    *
* 6.RECKHOW, 1977 qs<50 m/y     57      112       45     151    *
* 7.RECKHOW, 1977 qs>50 m/y      6       12        0      60    *
* 8.WALKER, 1977 GENERAL        92      180      101     226    *
* 9.VOLLENWEIDER, 1975          25       49       --      --    *
* 10.DILLON-RIGLER-KIRCHNER     31       61       --      --    *
* <= Range within which 95% of the observations should fall.   *
* See users manual discussion on the use of these models.      *
****************************************************************
```

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*****************************************************************
*                  PARAMETER RANGE MODULE                       *
*     Model input values MUST be within the range listed below. *
* ============================================================= *
*                        PARAMETERS                             *
*****************************************************************
* AREAL WATER LOADING <qs=z/Tw>  =  3.67E+00 m/yr               *
* INFLOW PHOSPHORUS CONC.<LTw/z> =  2.84E-01 mg/l               *
* MEAN DEPTH <z>                 =  5.18E+00 m                  *
* FLUSHING RATE <p>              =      0.71 /yr                *
* HYDRAULIC RETENTION TIME <Tw>  =      1.41 yr                 *
* AREAL PHOSPHORUS LOADING <L>   =   1044.30 mg/m^2-yr          *
* P = PREDICTED IN-LAKE PHOSPHORUS CONC.  mg/m^3                *
* ============================================================= *
*                                          Lakes in data base   *
* 1. WALKER, 1985 RESERVOIR MODEL                     (41)      *
*  1.5 < z < 58 m    0.13 < Tw < 1.91 yr                        *
*  0.014 < LTw/z < 1.047 mg/l                   P=      65      *
* ------------------------------------------------------------- *
* 2. CANFIELD-BACHMANN, 1981 NATURAL LAKE MODEL      (704)      *
*  4< P < 2600 mg/m^3  30< L < 7600 mg/m^2-yr                   *
*  0.2< z <307 m       0.001< p <183/yr         P=     101      *
* ------------------------------------------------------------- *
* 3. CANFIELD-BACHMANN, 1981 ARTIFICIAL LAKE MODEL   (704)      *
*  6< P <1500 mg/m^3   40< L <820,000 mg/m^2/yr                 *
*  0.6< z <59 m        0.019< p <1800/Yr       P=       67      *
* ------------------------------------------------------------- *
* 4. RECKHOW, 1979 NATURAL LAKE MODEL                 (47)      *
*  4 < P < 135 mg/m^3    70 < L <31,400 mg/m^2-yr               *
*  0.75< qs <187 m/yr                          P=       65      *
* ------------------------------------------------------------- *
* 5. RECKHOW, 1977 ANOXIC LAKE MODEL                  (21)      *
*  17< P < 610 mg/m^3 0.024< LTw/z< 0.621mg/l  P=      208      *
* ------------------------------------------------------------- *
* 6. RECKHOW, 1977 OXIC LAKES  qs < 50 m/yr           (33)      *
*  P < 60 mg/m^3    LTw/z < .298 mg/l          P=      108      *
* ------------------------------------------------------------- *
* 7. RECKHOW, 1977 LAKES WITH  qs > 50 m/yr           (28)      *
*  P < 135 mg/m^3    LTw/z < 0.178 mg/l                         *
*  Tw < 0.25 yr       z < 13 m                 P=       57      *
* ------------------------------------------------------------- *
* 8. WALKER, 1977 GENERAL LAKE MODEL                 (105)      *
*  P< 900 mg/m^3     LTw/z < 1.0 mg/l          P=      143      *
* ------------------------------------------------------------- *
* 9. VOLLENWEIDER, 1975  GENERAL LAKE MODEL                     *
*    NOT AVAILABLE                             P=       76      *
* ------------------------------------------------------------- *
* 10. DILLON, RIGLER, KIRCHNER, 1975 GENERAL LAKE MODE  (15)    *
*  P < 15 mg/m^3      107 < L < 2210 mg/m^2-yr    P=    82      *
*  1.5< qs <223 m/yr   0.21<  p < 63/yr                         *
*****************************************************************
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*******************************************************************
*                    LAKE CONDITION MODULE                        *
*                                                                 *
* ============================================================== *
* ENTER THE AVE. SPRING MIXED T. PHOSPHORUS =      26     mg/m^3  *
* --------------------------------------------------------------- *
* THE GROWING SEASON CHLOROPHYLL a =      11 mg/m^3               *
* --------------------------------------------------------------- *
* ENTER THE AVE. GROWING SEASON CHLOROPHYLL a      15 mg/m^3      *
* --------------------------------------------------------------- *
* THE MIXED NATURAL LAKE SECCHI DEPTH        =     1.26 m         *
* THE STRATIFIED NATURAL LAKE SECCHI DEPTH =       1.64 m         *
* --------------------------------------------------------------- *
* THE MIXED IMPOUNDMENT SECCHI DEPTH         =     1.07 m         *
* THE STRATIFIED IMPOUNDMENT SECCHI DEPTH    =     1.54 m         *
* --------------------------------------------------------------- *
* Regressions from:  (Lillie, Graham and Rasmussen, 1993)         *
* --------------------------------------------------------------- *
*                  TROPHIC STATE INDICIES                         *
* --------------------------------------------------------------- *
* ENTER TOTAL PHOSPHORUS   =       26 mg/m^3    T.S.I  =     53   *
* ENTER CHLOROPHYLL a      =       15 mg/m^3    T.S.I  =     55   *
* ENTER SECCHI DISC DEPTH =      2.4 meters     T.S.I  =     47   *
*******************************************************************
*              WATER AND NUTRIENT OUTFLOW MODULE                  *
*                                                                 *
* ============================================================== *
* THE AVE. ANNUAL INLAKE TOTAL PHOSPHORUS  =        26 mg/m^3     *
*                                                                 *
* ANNUAL DISCHARGE         = 1.46E+04 AF       1.80E+07 m^3       *
*                                                                 *
* ANNUAL OUTFLOW LOADING =     202.9 LB           447.5 Kg        *
*******************************************************************
```