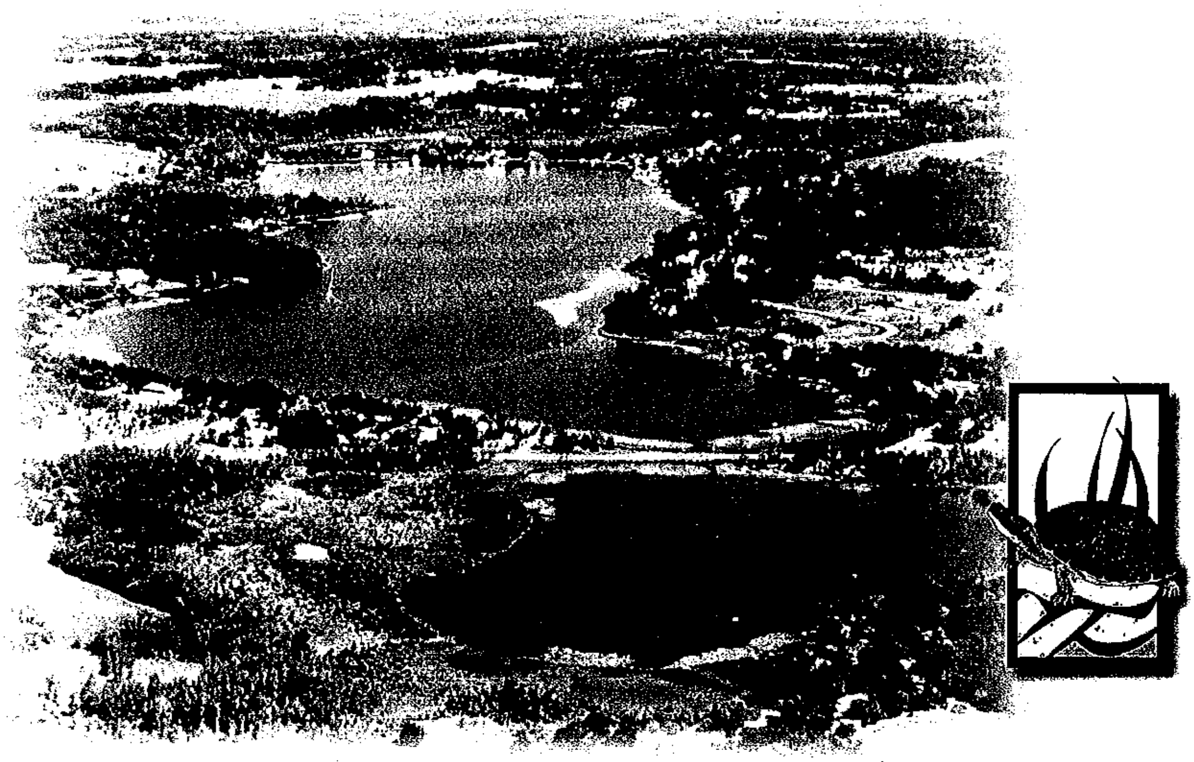


Comfort Lake, Chisago County Phase I Resource Investigation

A Clean Water Partnership Project

April 2000
Revised February 2001 and
September 2002

Prepared by: Steve McComas, Blue Water Science with assistance from Schuler Environmental Engineering, Comfort Lake Association, Wyoming Township and MPCA

Comfort Lake, Chisago County
Phase I Resource Investigation

Table of Contents

ACKNOWLEDGMENTS

We would like to acknowledge the help of the volunteers and professionals who assisted on this project. They include:

Jackie Anderson, Project Representative, Wyoming Township

Diana McEvoy, Comfort Lake Association

Steve Schriber, Comfort Lake Volunteer

Mayor Raymond Daninger, City of Forest Lake

Mary Darragh Schmitz, Chisago County Water Plan Coordinator

Mike Mueller, MnDNR Hydrologist

Shannon Lotthammer, MPCA - Project Manager

Celine Lyman, MPCA - Project Manager

Norma Olson, Town Clerk

Lisa Hughs, Zoning Administrator

Nancy Blomberg, Town Secretary

Steve McComas, Blue Water Science, and **Dave Schuler**, Schuler Environ. Engineering

Eco-Agri Laboratories, Willmar, and **Minnesota Department of Health** conducted lab analysis

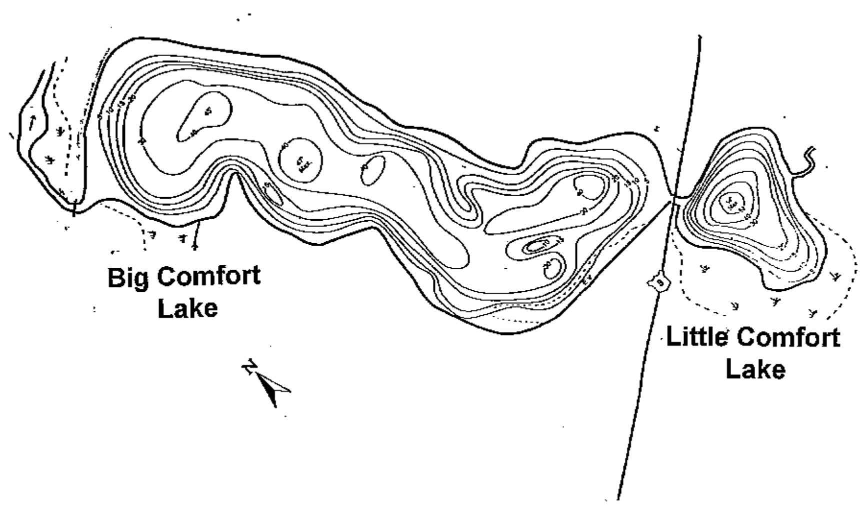
Comfort Lake, Chisago County
Phase I Resource Investigation

Summary

Project Background
The water quality and condition of Comfort Lake was classified by the 1994 MPCA Lake Assessment Program (LAP) Study as borderline mesotrophic-eutrophic for Big Comfort and eutrophic for Little Comfort. Secchi readings taken by the Lake Association through the 1990s indicated a decline in the clarity of the lake and an increase in the phosphorus content of the lake (based on monitoring). Development within the lake's watershed has been intense through the 1990s as well. Forest Lake and Wyoming Township have seen rapid growth in commercial and residential developments.

Reasons for the Study
The purpose of this study was to conduct a scientific investigation of the lake and its watershed and in particular the nutrient loading from the watershed. Then to evaluate the data, to evaluate water quality trends, and to prepare an implementation plan to reduce nuisance algae blooms in Comfort Lake based on the sources of excessive nutrient loading.

Other issues that were to be addressed were shoreline aquatic vegetation, and the influence development impacts on shoreline vegetation, including lilies.



Lake contour map for Big and Little Comfort Lakes.

Lake Water Quality Goals

Topic Area	Existing Conditions	Goals
Nutrients	Summer average phosphorus concentration is 40 ppb for Big Comfort and 58 ppb for Little Comfort Lake.	Reduce summer average phosphorus to 35 ppb or less.
Water Clarity	Summer average is 4.3 feet for Big Comfort and 3.9 feet for Little Comfort Lake.	Maintain summer average transparency of at least 6 to 7 feet.
Algae	Algae blooms are increasing in duration.	Reduce summer algal blooms.
Weeds	Nuisance growth of curlyleaf pondweed occurs and native plant coverage is low.	Reduce nuisance acreage by 50%. Maintain diverse native aquatic plant community that covers 40% of bottom area.
Fish	Average to above average northern pike community, with high carp numbers.	Add bass and maintain predator control of forage fish through catch and release.
Wildlife	Typical Chisago County diversity.	Improve wood duck habitat and shoreline areas to encourage other bird species and discourage geese nesting.
Water Use Conflicts	Moderate boat traffic and lake use	Maintain moderate boat traffic and reasonable hours.

The future nutrient inputs needed to meet lake phosphorus goals represent a 50% phosphorus load reduction to Big Comfort and a 30% phosphorus load reduction to Little Comfort Lake.

Watershed Characteristics

	Big Comfort Lake	Little Comfort Lake
Direct drainage area:	603 acres	200 acres
Contributing surface watershed:	20,972 acres	9,341 acres
Total watershed:	21,575 acres	9,541 acres
Important lakes in the watershed:	Forest Lake, School Lake, Bone Lake	

Lake Characteristics

	Big Comfort	Little Comfort
Area	219 acres (89 ha)	37 acres (15 ha)
Mean depth	19.1 feet (5.8 m)	17.8 feet (5.4 m)
Maximum depth	45 feet (13.7 m)	54 feet (16.5 m)
Volume	4,179.3 acre-feet (5.2 hm^3)	664.7 acre-feet (0.82 hm^3)
Littoral area (area where plants grow)	41%	44%
Fetch (length of the lake)	0.9 mile (1.5 km)	0.3 mile (0.51 km)
Watershed : Lake Surface Ratio	88	256
Estimated Average Water Residence Time:	0.58 years	0.18 years

Big and Little Comfort Lakes Water Chemistry Summary

A summary of water chemistry results for 1994 and 1998 for the Comfort Lakes is shown below. Phosphorus levels are slightly higher and secchi disc transparencies are slightly lower in 1998 compared to 1994. Nitrogen is the same. Big Comfort and Little Comfort Lake have slightly lower secchi disc transparencies for lakes in the North Central Hardwood Forest (NCHF) Ecoregion compared to the typical NCHF range. For total phosphorus, Big Comfort fits within the range and Little Comfort Lake does not.

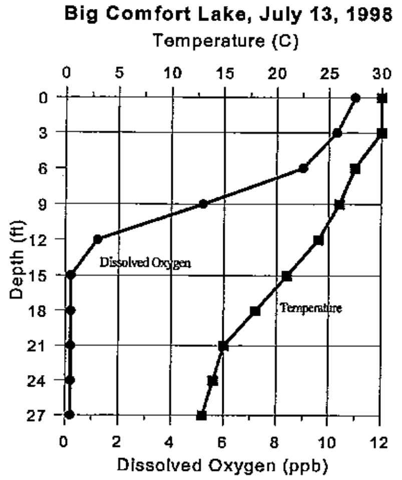
Summary of Big Comfort and Little Comfort Lakes data for 1994 and 1998.

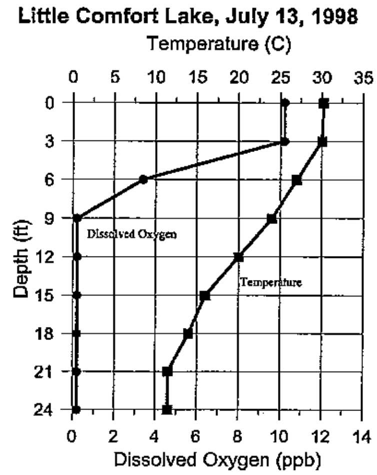
Parameter	Big Comfort		Little Comfort		Typical Range for NCHF Ecoregion
	1994	1998	1994	1998	
Total Phosphorus (ppb)	35	40	51	58	23-50
Chlorophyll a (ppb)					
Mean	16	11	32	15	5-22
Maximum	30.4	24	56.7	37	7-37
Secchi disc (feet)	6.5	4.3	5.8	3.9	4.9-10.5
Total Kjeldahl Nitrogen (mg/l)	1.1	1.1	1.3	1.2	0.62-1.2
Nitrite + Nitrate - N (mg/l)	0.05	<0.01	0.05	<0.01	<0.01
Alkalinity (mg/l)	155	172	140	164	75-150
Color (Pt-Co Units)	35	--	45	--	10-20
pH (SU)	8.2	8.1	8.3	7.9	8.6-8.8
Chloride (mg/l)	19	--	9.3	--	4-10
Total Suspended Solids (mg/l)	4.3	--	4.4	--	2-6
Total Suspended Inorganic Solids	1	--	0.8	--	1-2
Turbidity	2.3	--	2.8	--	1-2
Conductivity (umhos/cm)	313.3		263.8		300-400
TN:TP Ratio	33:1		27.1		25:1-35:1

* North Central Hardwood Forest Ecoregion

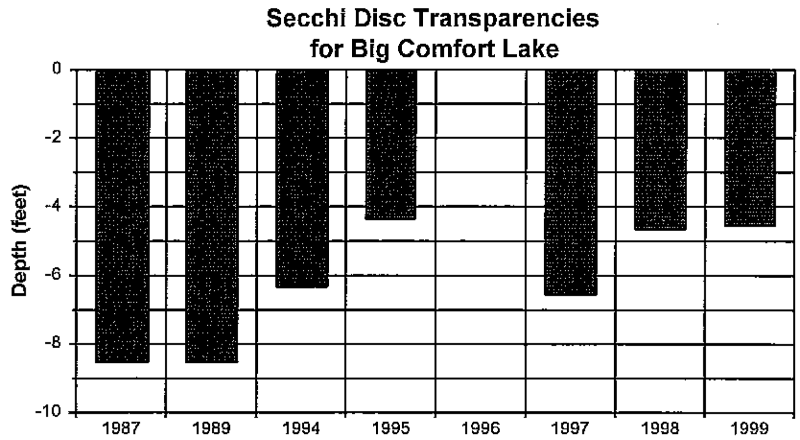
Big and Little Comfort Lakes Water Quality Conditions

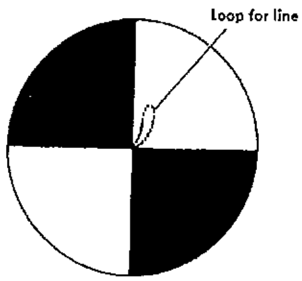
Dissolved Oxygen
Both Big and Little Comfort Lakes stratify by temperature over the summer. By mid summer, oxygen in the bottom water is depleted. Often this starts a process that results in phosphorus release from the lake sediments. This is occurring in both lakes.





Clarity
Average summer water clarity was less in 1998 compared to 1987 and 1989 for Big Comfort Lake. The goal is to maintain a summer average transparency of 6 to 7 feet.

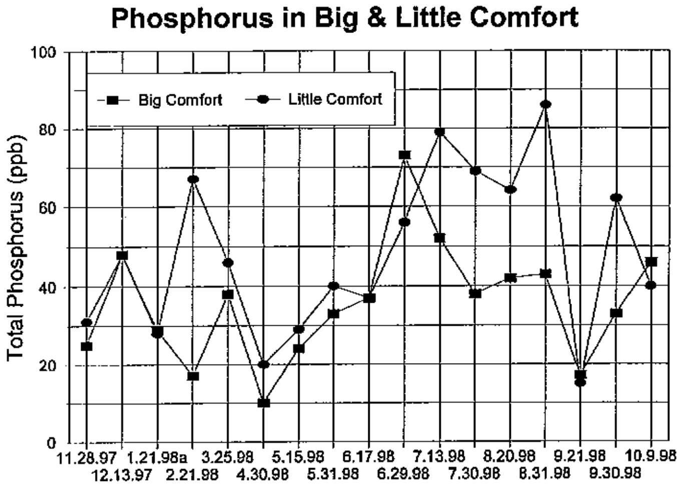




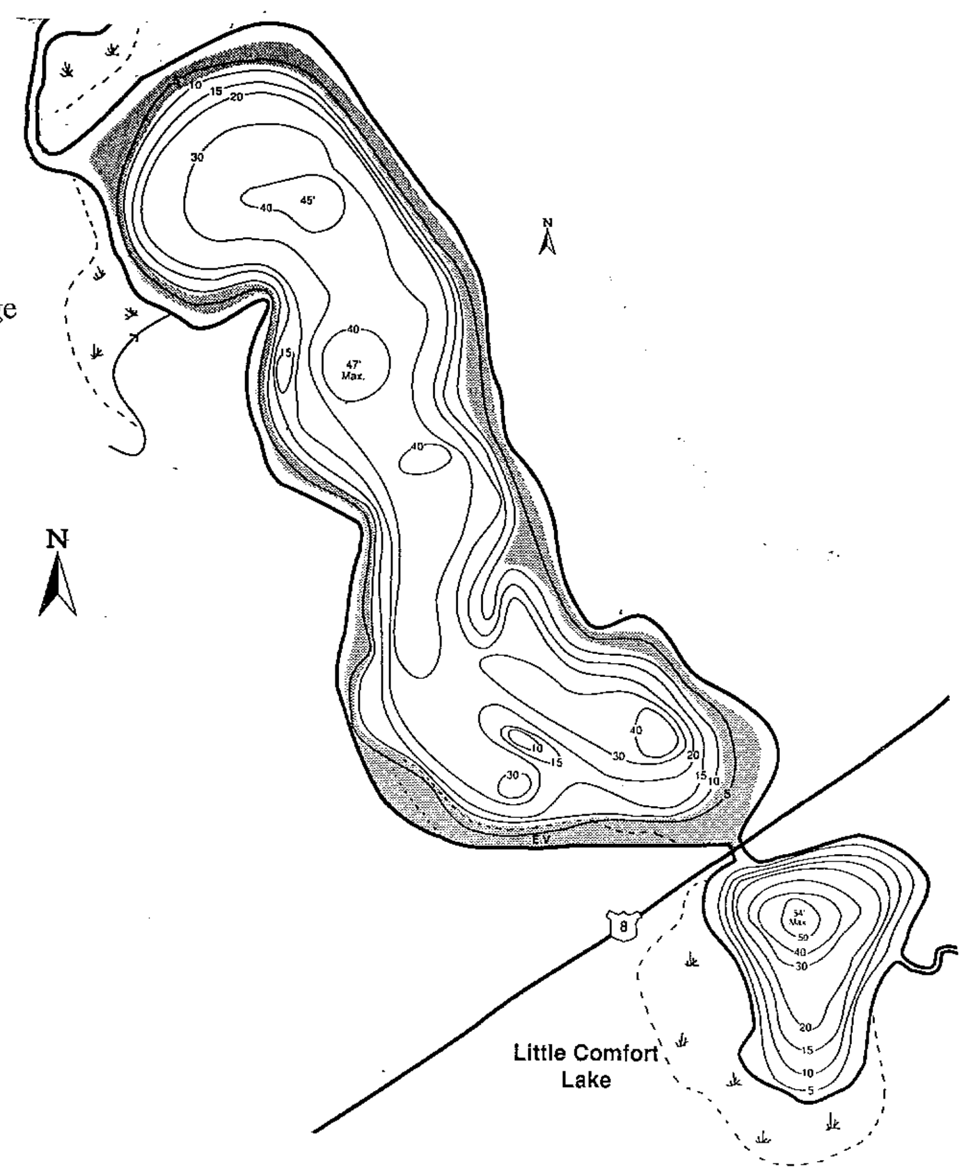
Secchi disc.

Secchi disc is used to measure clarity.

Phosphorus
Average summer phosphorus concentrations were 40 ppb for Big Comfort and 58 ppb for Little Comfort. The goal for the summer average is around 35 ppb.



Aquatic Plants
There is a low density coverage of aquatic plants around Big Comfort Lake and slightly denser coverage around Little Comfort. Increasing plant density and coverage in Big Comfort Lake will improve water quality.



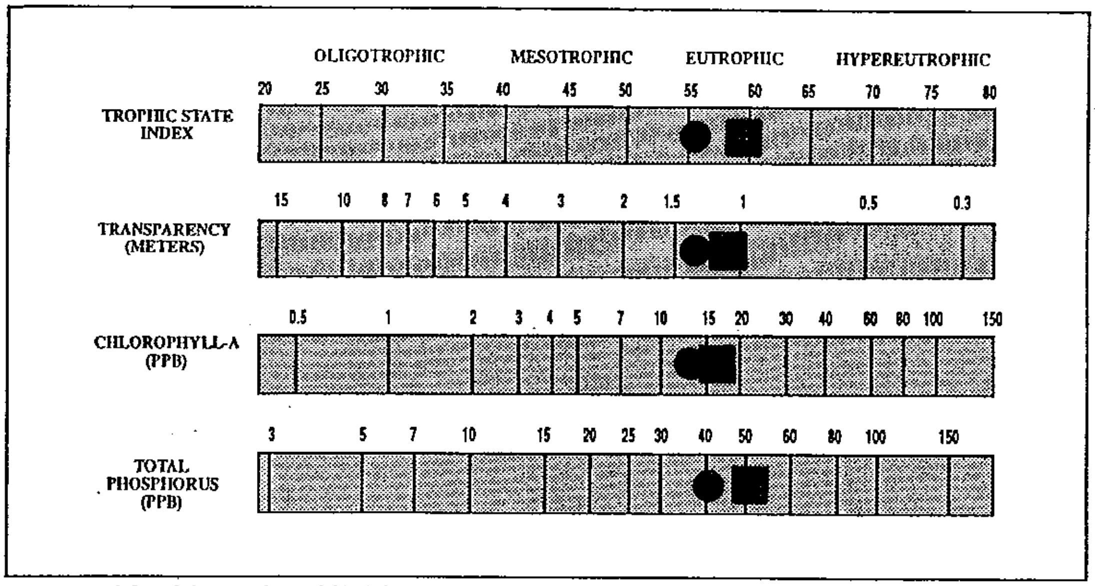
Trophic State Index (TSI) for Big and Little Comfort Lakes

- based on the Carlson Trophic State Index.
- measures lake fertility on a scale from 1-100.
- Big and Little Comfort Lakes are eutrophic.

Carlson's Trophic State Index

R.E. Carlson

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



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

● = Big Comfort Lake

■ = Little Comfort Lake

Watershed Conditions

Amount of Water Running Off the Land (by subwatersheds). Watershed runoff characteristics for the period of flow recording was Feb 27-Oct 12, 1998, a total of 228 days. Rainfall for the period was approximately 24 inches. Average annual rainfall is about 28 inches. Subwatershed locations are shown on p. viii.

Sub-watershed	Average Daily Flow (cfs)	Acre-ft per Day	Ac-ft Over 228 Day Period	Watershed Size (ac)	Inches of Runoff per Acre	% Runoff
Big Comfort						
1	0.51	1.01	230	1,357	2.04	8%
2	1.82	3.61	823	1,641	6.01	25%
5	--	--	543	1,861	3.50*	14%
4	--	--	6,293**	6,535	11.56**	48%
1, 2, 4, 5	17.43	34.6	7,889	11,394	8.31	35%
Little Comfort						
3	4.81	9.54	2,175	9,341	2.80	12%

*Estimated based on more impervious surface than subwatershed 1 but less than subwatershed 2.
**Estimated by substracting flows of subwatersheds 1,2, and 5 which equals 1,596 ac-feet for the 228 day period from total flow measured which was 7,889 ac-ft, leaving 6,293 acre-feet.

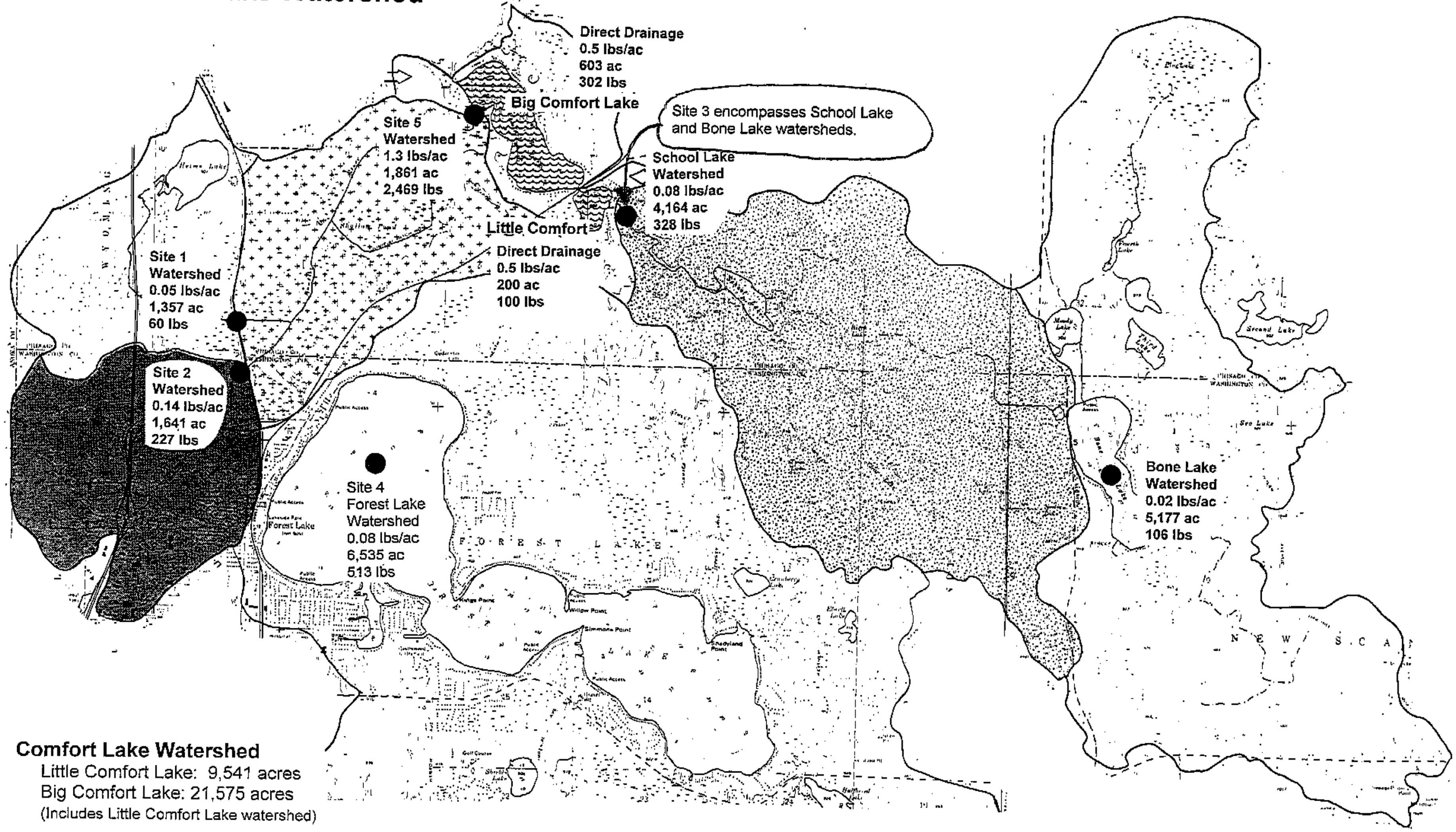
Current Phosphorus Levels and Phosphorus Reductions Needed to Improve Comfort Lakes

BIG COMFORT LAKE				LITTLE COMFORT LAKE			
	Existing Budget (kg phosphorus)		Future P Budget Needed to Reach 35 ug/l (kg/yr)		Existing Budget (kg phosphorus)		Future P Budget Needed to Reach 35 ug/l (kg/yr)
	6 month	Year			6 month	Year	
Sub 1	27	33	31	Bone Lake	48	59	50
Sub 2	103	121	65	Sub 3	149	182	122
Sub 4	233	268	200	Subtotal	197	241	172
Sub 5	1,155	1,397	560				
Subtotal	1,518	1,819*	856				
Little Comfort	—	117**	80***				
Direct Drainage	—	214	107	Direct Drainage	—	45	22
Subtotal	—	2,150	1,043	Subtotal	197	286	194
Septic tanks	—	10	10	Septic tanks		2	2
Rainfall	—	24	24	Rainfall		4	4
Subtotal	—	34	34	Subtotal		6	6
Total	—	2,218	1,077	Total		292	200

*Flow for rest of year was 2.5 hectometers at 120 ppb = 300 kg.
**Little Comfort phosphorus concentration = 58 ppb x 2.01 hectometers = 117 kg
***Little Comfort phosphorus concentration reduced from 58 ppb to 40 ppb.

The future nutrient inputs needed to meet lake phosphorus goals represent a 50% phosphorus load reduction to Big Comfort and a 30% phosphorus load reduction to Little Comfort Lake.

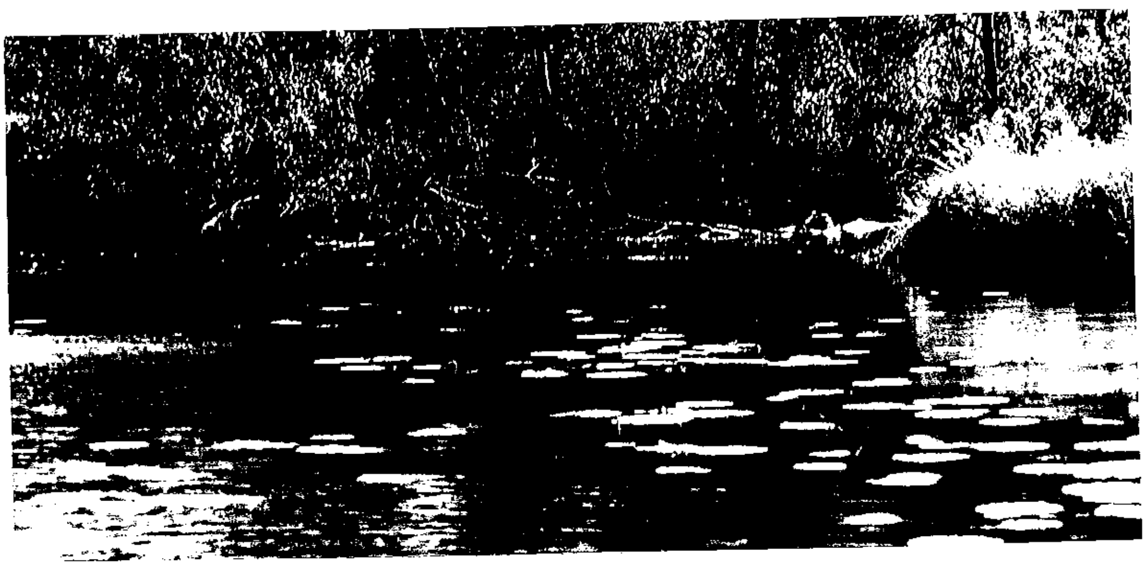
Phosphorus Loading from Subwatersheds In the Comfort Lake Watershed



A summary of phosphorus loading sources and quantities to Comfort Lake. Loads vary from year to year. The subwatershed at Site 5 seems to be a significant source of phosphorus. The pounds of phosphorus per acre values were based on monitoring flows and phosphorus concentrations from April through September, 1998.

Important Findings of this Study

- Watershed area to Big Comfort Lake is 88 times larger than the surface area of Big Comfort Lake.
- Watershed area to Little Comfort Lake is 257 times larger then the surface area of Little Comfort Lake.
- Both Big and Little Comfort Lakes have large watersheds and are heavily influenced by watershed inflows. The main inflow is the Sunrise River (old JD 1 system)
- The runoff into Little Comfort Lake has high volume and low phosphorus concentrations. The resulting amount of phosphorus delivered to Little Comfort Lake is moderate, but high enough to account for the nuisance summer algae blooms in Little Comfort Lake.
- In recent years, in the Big Comfort Lake watershed, the increase in impervious surfaces has increased the quantity of stormwater runoff, while not greatly increasing the amount of phosphorus. However, the increased volume of stormwater coupled with problem culverts that hold back flow, apparently has increased saturation in a large wetland area in what is called Shallow Pond. The increase in saturation results in additional phosphorus leaching from the wetland peat. This wetland area then exports elevated amounts of phosphorus that are carried into Big Comfort Lake.
- Runoff in the direct drainage areas around Big and Little Comfort Lakes are an important nutrient source to control for water quality improvements.
- Over 50% of the lots in the Big Comfort shoreland fringe around the lake have a native buffer strip.
- Land use in the watershed of Big Comfort Lake has changed dramatically in the recent 10 year period. Within the Comfort Lake watershed area, over 300 housing units have been added in Wyoming Township and 30 acres in Forest Lake have converted from open fields to commercial area with increasing 100% imperious surfaces.
- Lake improvement projects in this study address watershed, shoreland, and lake areas.



Summary of Proposed Watershed, Shoreland, and Lake Projects for Comfort Lake

Projects	How They Benefit Water Quality
Watershed Projects	
1. Implement stormwater BMPs for commercial development in Subwatersheds 1 and 2.	With residential and commercial development ongoing in these 2 critical subwatersheds it is important that stormwater runoff water quality projects continue to be implemented.
2. Implement, where feasible, infiltration and runoff rate controls in all subwatersheds.	Reducing the volume of runoff even 10% through small-scale infiltration efforts could reduce flooding in Subwatershed 5 and reduce phosphorus release from saturated wetland sediments.
3. Lower culvert in Sunrise River in Subwatershed 5.	One culvert apparently is set too high in Subwatershed 5. This may be acting like a dam. Lowering the culvert may reduce water back-up and therefore reduce flooding or wetness in the Shallow Pond wetland complex.
4. Install linear ditch aeration in Subwatershed 5 (pending results of other linear ditch systems).	Aerating slow moving ditch water high in phosphorus and iron may precipitate iron which in turn would serve to scavenge dissolved phosphorus and make it biologically unavailable.
Shoreland Projects	
5. Promote shoreland restoration emphasizing native plant conditions and enforcement of shoreland regulation by local zoning authority.	Native landscaping and lakescaping improve runoff water quality and help attract wildlife. Buffer strips and shoreland vegetation reduce nutrient loading to the Comfort Lakes.
6. Maintain onsite systems.	Septic systems are mostly in good working order. Maintenance and ongoing education should help to keep them from being either an environmental health problem or a water quality problem.
Lake Projects	
7. Remove roughfish through the use of carp traps and commercial fishing.	Use commercial fishermen to fish down the carp population in both Comfort Lakes. Carp may be limiting aquatic plant growth in Big Comfort Lake. Reducing carp may improve plant coverage.
8. Install carp barriers to reduce carp movement into Judicial Ditch 1 (Sunrise River).	If carp can be fished down to lower numbers, carp barriers could inhibit movement into the Sunrise River for spawning, helping to keep carp recruitment down in the Comfort Lakes.
9. Conduct lake soil testing to set-up contingency plan for Eurasian watermilfoil invasion.	Milfoil has not been found at the present time. Lake soil testing will delineate areas that could produce nuisance growth. Lake mapping will then help determine a management approach and level of effort needed to control nuisance growth.
10. Develop program to promote native plants and reduce spraying. Transplant macrophytes if they don't come back after fish removal.	Native plants need to cover more area then they presently do to sustain good water quality.
11. Maintenance dredging around culverts, especially off Highway 8.	Maintenance dredging around culverts at Highway 8 will help maintain water flow from Little to Big Comfort. Other culverts need maintenance also.
12. Whole lake alum project (reserve project to be implemented if needed)	An alum application in both Little and Big Comfort Lakes would reduce phosphorus loading from lake sediments. This is a reserve project meaning it may not be needed if other management projects achieve water quality improvements. It would be scheduled for Year 4 or 5, putting it in Part 2 of a Phase II program.
Education Program	
• Promote pollution prevention by landowners on a watershed basis. This would target nutrient source reduction and be done through information and education programs.	Landowners in the direct drainage area have control of what runs off their property into the lake. Fertilizer use and landscaping are areas of active involvement. I&E programs will give a full range of options for pollution prevention techniques that keep nutrients from entering lakes and wetlands in the watershed.
• Community Education program which includes public access rules for Little Comfort Lake, fish limits for lakes, snowmobile trails, etc.	Framework should be established for transmitting shoreland rules, public access rules, snowmobile regulations, and even fishing limit laws to residents and the general public with a mechanism for enforcement.
• Coordinate efforts of local and state agencies to enforce shoreline and lake rules and regulations	Shoreland rules are emerging at the state and county levels. Shoreland includes the upland fringe, the shoreline, and shallow water. Rules need to be well publicized with a mechanism for enforcement.
Ongoing Programs	
• Establish Ordinary High Water Level elevations for Big and Little Comfort Lakes and a maintenance program.	The MnDNR will install a fixed crest weir at the outlet of Big Comfort in 2000. This will help maintain lake levels at the mean water level (886.0').
• Implementation of surface water management plan in Wyoming Township.	Stormwater management practices should continue to be implemented with new development.
• Intergrated water management policies through the Watershed District.	The Comfort Lake/Forest Lake Watershed District should be able to establish watershed wide policies that are consistent with good lake improvement goals.

Implementation Plan Budget: A summary of the project budget to improve water quality conditions in Big and Little Comfort Lakes is summarized below. Costs are based on a three year program. Additional cost details would be prepared in a Phase II application.

Program Element	Cost	State/ Federal (In Kind)	Local (In Kind)	MPCA (Grant) or Watershed District (cash)
1. Implementation Projects				
1. BMPs in Subwatersheds 1 & 2	$90,000	--	$45,000	$45,000
2. Infiltration and rate controls	100,000	--	50,000	50,000
3. Lower culverts in Subwatershed 5	7,000	--	--	7,000
4. Install aeration system in Ditch 1	20,000	--	--	20,000
5. Shoreland restoration	27,000	3,000	9,000	15,000
6. Maintain onsite systems	8,200	--	3,000	5,200
7. Remove roughfish	9,000	--	--	9,000
8. Install carp barriers	1,200	--	--	1,200
9. Plan for milfoil invasion	5,5000	--	1,500	4,000
10. Increase native aquatic plants	18,000	2,000	1,000	15,000
11. Maintenance around culverts	3,900	--	1,500	2,400
12. Whole lake alum treatment (reserve)	103,000	--	--	103,000*
Subtotal Element 1	**392,800**	**5,000**	**111,000**	**276,800**
2. Information and Education Program				
Newsletters, fact sheet	12,700	1,600	4,500	6,600
Informational meetings	5,200	1,200	2,000	2,000
Subtotal Element 2	**17,900**	**2,800**	**6,500**	**8,600**
3. Monitoring				
Routine lake and watershed	**51,000**	**3,000**	**3,000**	**45,000**
4. Project Management				
Project meetings/administration	25,000	2,000	4,000	19,000
Reports	21,000	--	--	21,000
Expenses & Misc	9,000	2,000	4,000	3,000
Subtotal Element 4	**55,000**	**4,000**	**8,000**	**43,000**
TOTALS	**$516,700**	**$14,800**	**$128,500**	**$373,400**

* Alum treatment is a reserve project that may not be needed if lakes improves.

Notes:

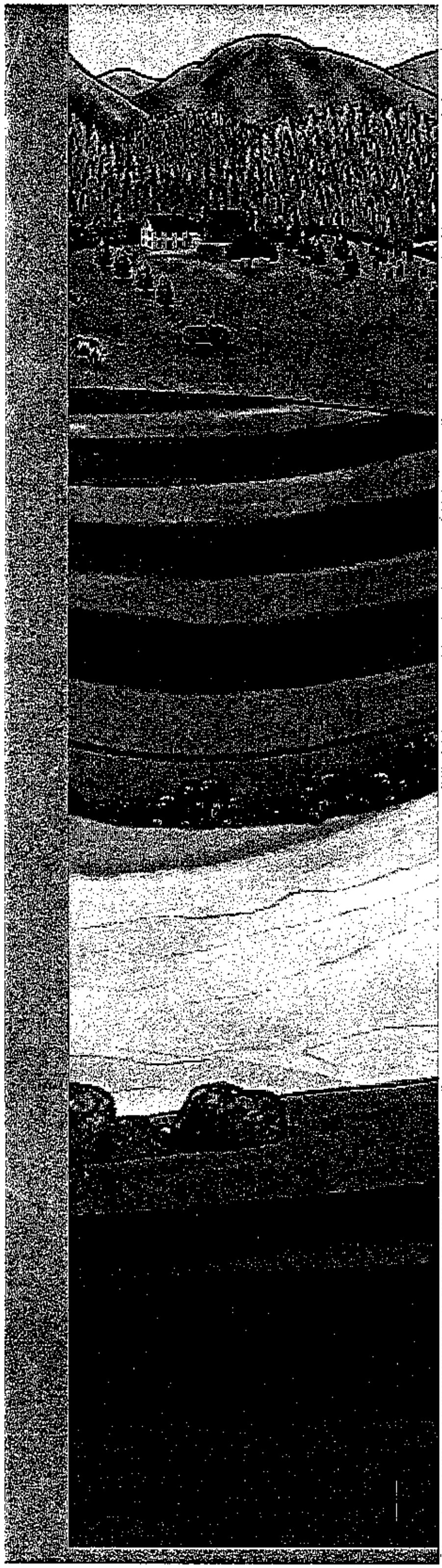
- Local in-kind match to a Clean Water Partnership grant represents several sources of funds. For stormwater projects, developers of new developments assume major roles for installing "Best Management Practices" (BMPs) in the watershed especially in Subwatersheds 1 and 2. This represents a minimum of $100,000 over a 3-year period of an in-kind match to an MPCA grant. Some stormwater BMPs may not be eligible for a match.

- Within the "MPCA grant or Watershed District cash" column, is an alum project for $103,000. This may not be needed if the lakes improve. It would be scheduled for 4 or 5 years down the road. Monitoring and some of the administration costs could be picked up by the Watershed District.

United States Department of Agriculture
Soil Conservation Service

Program Aid Number 420

What is a Watershed?



What is a watershed?

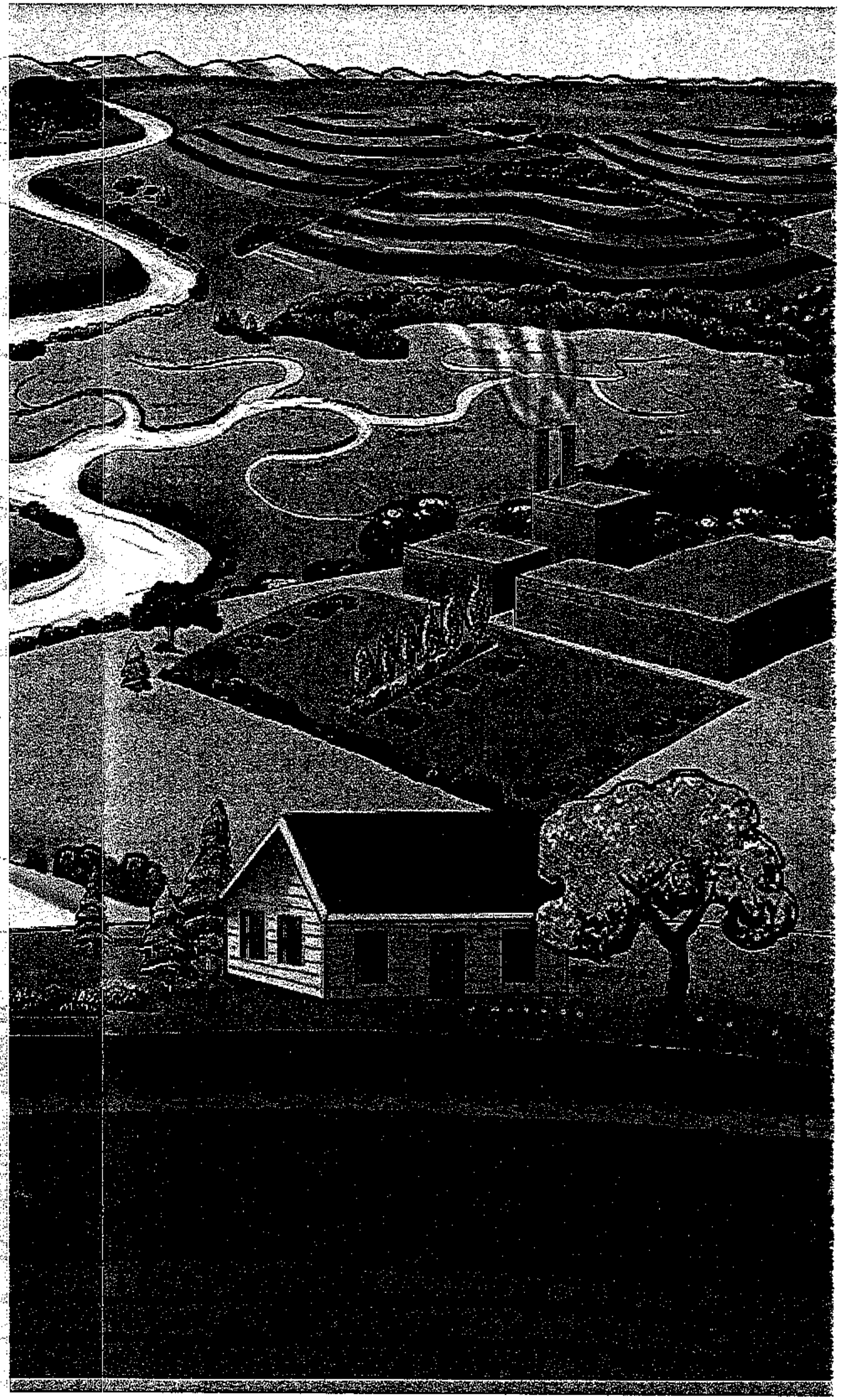
It's the land that water flows across or under on its way to a stream, river, or lake.

How do watersheds work?
The landscape is made up of many interconnected basins, or watersheds. Within each watershed, all water runs to the lowest point—a stream, river, or lake. On its way, water travels over the surface and across farm fields, forest land, suburban lawns, and city streets, or it seeps into the soil and travels as ground water. Large watersheds like the ones for the Mississippi River, Columbia River, and Chesapeake Bay are made up of many smaller watersheds across several states.

Are all watersheds the same?
Not at all. Watersheds come in many different shapes and sizes and have many different features. Watersheds can have hills or mountains or be nearly flat. They can have farmland, rangeland, small towns, and big cities. Parts of your watershed can be so rough, rocky, or marshy that they're suited only for certain trees, plants, and wildlife.

Your watershed community.
Everyone lives in a watershed. You and everyone in your watershed are part of the watershed community. The animals, birds, and fish are, too. You influence what happens in your watershed, good or bad, by how you treat the natural resources—the soil, water, air, plants, and animals. What happens in your small watershed also affects the larger watershed downstream.

There are many things you and your watershed community can do to keep your watershed healthy and productive. To learn what you can do to take care of your watershed, call 1-800-THE-SOIL or your local Soil Conservation Service office. It's listed in the telephone book under U.S. Government, Department of Agriculture.



We all live in a watershed.

Everything we do in our watershed affects the soil, water, air, plants, and animals.

Let's work together to keep our watersheds healthy. Here are some things you can do.

1
On the farm

Keep plant residue on the surface of sloping cropland. This reduces runoff and prevents sediment, fertilizers, and pesticides from entering streams, rivers, lakes, and ponds.

2
At home

Landscape your yard with plants that need a minimum of water and fertilizer. Use only the amount of fertilizers and pesticides that plants need.

3
In your community

Protect wetlands that serve as natural buffers against pollution, soil erosion, and flooding.

Revised: September 1994

Printed on Recycled Paper

Eutrophication

Phosphorus Overload or Phosphorus Recycling?

A Review of an Alternate Approach from Europe

NSFC ENGINEERING SCIENTIST
David A. Pask

A fairly recent issue of *Scope Newsletter* offers an alternate insight into shallow lake eutrophication in an article titled "Shallow Lakes, Biomanipulation and Eutrophication" by Brian Moss of the University of Liverpool, UK. This publication of the Centre European d'Etudes des Polyphosphates (CEEP) is sponsored by the European Chemical Industry Council.

This 2-page discussion is applicable to Big Comfort Lake.

Eutrophication is the process by which a rich flow of nutrients into a body of water, especially a lake or pond, causes excessive growth of aquatic plants, particularly algae. This article appears to offer a scientific explanation for the lack of success in the counteraction of eutrophication by conventional limitation of phosphorus and some success in alternate treatments.

The premise is that the theories of phosphorus as a limiting nutrient were developed from observation and analysis of deep lakes. The majority of lakes and waters of our concern are shallow, and different mechanisms of nutrient balance are in operation.

In any water body, the balance of nutrients, principally nitrogen (N) and phosphorus (P), is a function of inflow from the watershed (including lakeshore development), outflow, denitrification to the atmosphere, and settlement of P as organic or precipitated material to the lake bottom. Compared to a deep lake, there is, in a shallow lake, severe denitrification to the atmosphere (a function of area/volume) and major recycling of P between sediments, plants, and water. Thus there is a major difference in N/P ratio between the two systems.

An understanding of the difference between the two systems has come from the lack of success in attempts to restore shallow lakes modeled on methods tested on deep lakes. These attempts took place in the Netherlands and Great Britain. Studies of these failures led to the hypothesis that in a eutrophied lake (dominated by algae); reeds, pondweeds, lilies, and other large plants cannot survive. But these plants are essential for the survival of zooplankton, which graze on algae, as they serve as a refuge from zooplankton-eating fish.

Without the plants, fish will eat almost all of the zooplankton and the growth of algae is no longer kept in check. A second factor in the ecology of the shallow lake is that the activity of bottom-feeding fish and other animal life stirs up the sediment in their search for food and, in doing so, resuspend P into the water column, providing nutrients for the regrowth of algae. Boat propellers can have similar effects.

The two states of a lake, a) clear water with larger weeds and reeds, and b) algal eutrophication, are essentially stable and self-sustaining. The two states can, however, be "switched," not only by limiting one or more nutrients but also by the removal and replacement of plant and fish species, or biomanipulation.

A lake in Wales had become eutrified after replacement of brown trout by common carp and other fish in the 1950s. In the 1990s, blooms of potentially toxic blue-green algae appeared, and warning notices on this recreational lake had to be posted. A study by the University of Liverpool concluded that the carp had acted as a "forward switch" to permanently change the state of the lake.

The lake was created by a dam and so could be drained to remove the existing fish. The lake was restocked with rudd, roach, pike, and crucian carp and replanted with lilies. (The common carp were sold to angling clubs for restocking private waters.) The lake is now recovering and is much clearer than it has been in decades.

A seven-step restoration strategy is suggested:

1) diagnosis of the problem and establishment of the target for restoration,
2) removal of existing or potential forward switches,
3) reduction of nutrient loading,
4) biomanipulation,
5) re-establishment of plants,
6) re-establishment of an appropriate fish community, and
7) monitoring of the results.

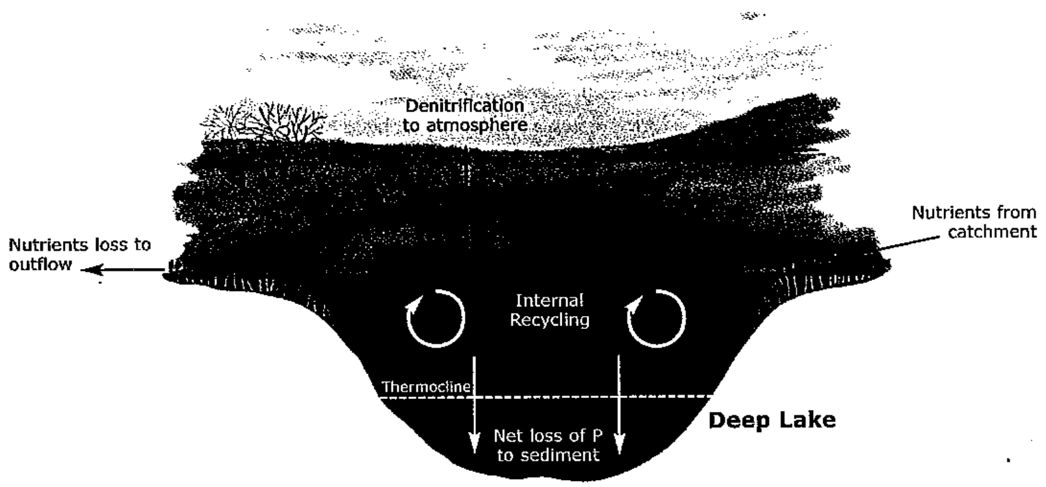
All of these steps are given in detail in the original text.

I cannot give an opinion as to how this science relates to conditions in North American shallow lakes, but I do recommend to those with an interest in this field that they read the original article and the referenced material.

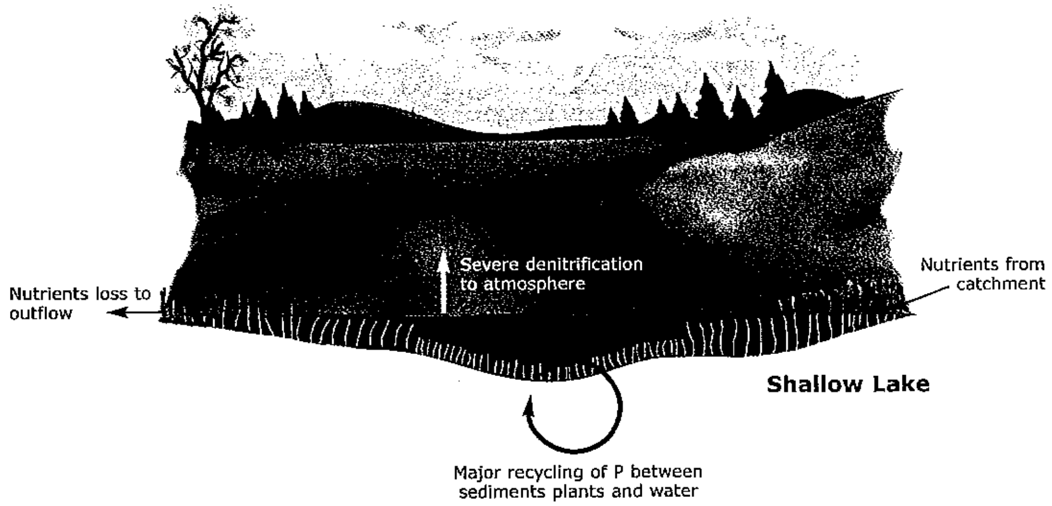
The complete article may be seen on the Scope Web Page, listed below. The publisher may be able to provide a limited number of the original publication and has given the Clearinghouse permission to copy the material. We cannot, unfortunately, reproduce the beautifully colored graphics, but can provide photocopies for the cost of reproduction.

The original article appeared in *Scope Newsletter*, Number 29, October 1998, published by CEEP. The *Scope Newsletter* seeks to promote the sustainable use of phosphates through recovery and recycling and a better understanding of the role of phosphates in the environment. Back issues of the newsletter are available at *http://www.ceep-phosphates.org*. Articles about phosphorus recovery and recycling can be found at *http://www.nhm.ac.uk/mineralogy/phos/index.html*. SF

Major Pathways of Nutrients in Deep...



...and Shallow Lakes



Adapted with permission from "Shallow Lakes, Biomanipulation and Eutrophication," *Scope Newsletter*, no. 29 (October 1998).

I. General Information

I.1. Introduction and Project Background

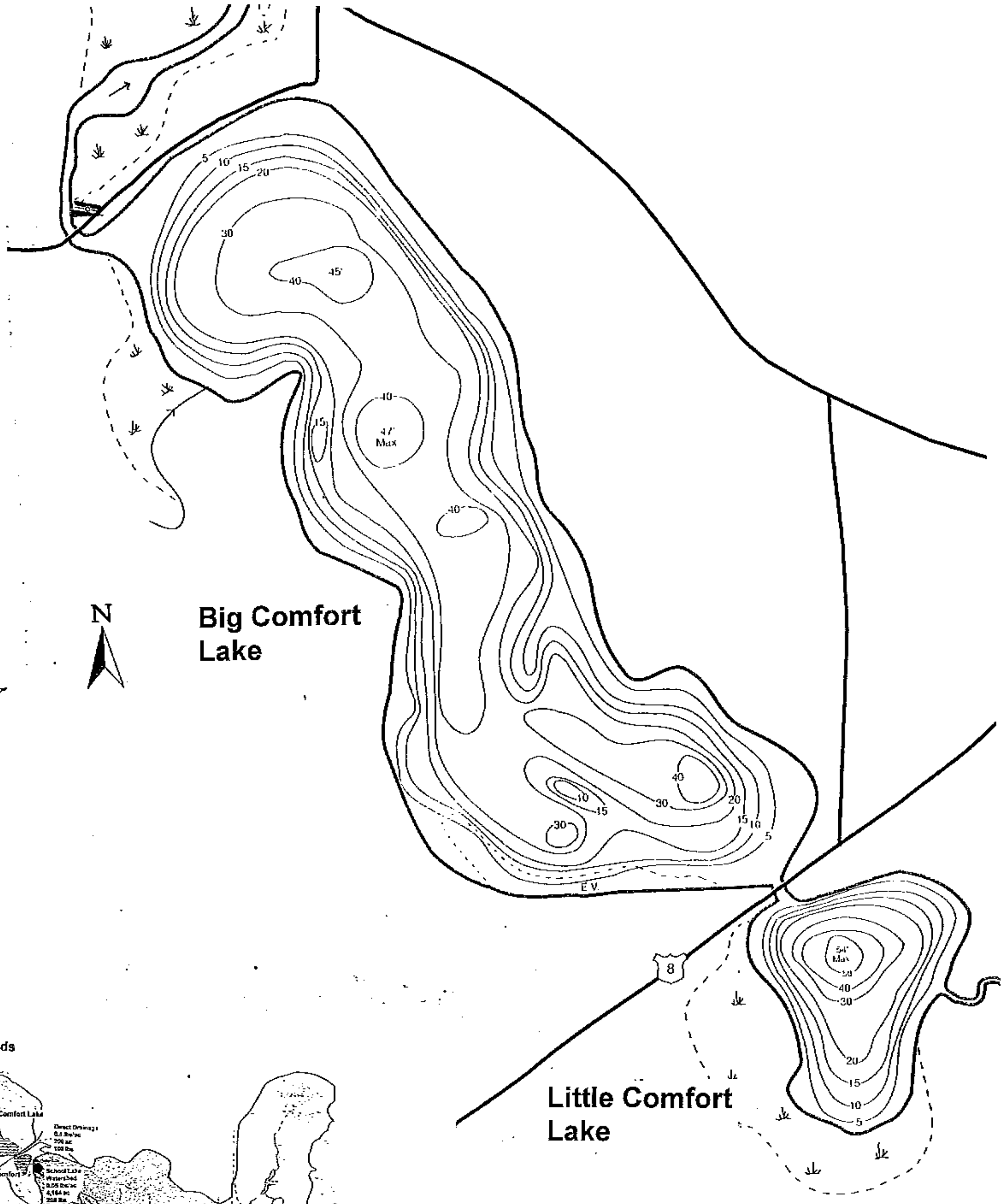
Big and Little Comfort Lakes are located in Wyoming Township, Chisago County, Minnesota. A contour map of the lakes is shown in Figure 1.

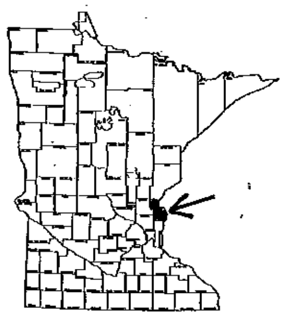
The overall goal of this project is to improve water quality in Comfort Lake to a realistic level (characteristic levels for minimally impacted North Central Hardwood Forests ecoregion). To do this we must determine the source of the problems. Typically, too much phosphorus is the problem, and there are several sources to consider, which include:

- agricultural runoff
- stormwater runoff from developed areas
- runoff from lakeshore lots
- rainfall
- groundwater
- phosphorus cycling from the lake sediments

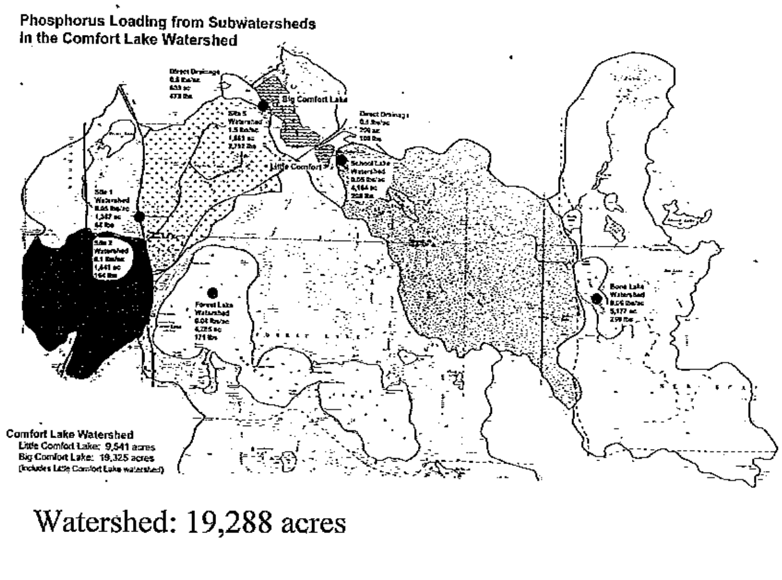
To characterize these sources, which would then allow us to implement projects and improve the water quality of Comfort Lake, the following steps were planned: 1) Determine the source of pollutants entering the lake by monitoring of inflow and outflow streams, 2) Determine the magnitude of phosphorus released from the lake sediments, and 3) Determine the impact of eutrophic wetlands on the nutrient budget.

The goals are to improve the water quality of Comfort Lake which will in turn optimize swimming, fishing, and natural beauty of the resource for the long-term (future generations).





Location



Watershed: 19,288 acres

Figure 1. Contour map of Comfort Lakes, Chisago County, Minnesota.

I.1A. History of the Lake and Project Area

Volunteers from the Comfort Lake Association compiled a historical summary and is displayed in Table 1.

Table 1. Comfort Lake historical summary: 1800's to 1990's (prepared by the Comfort Lake Association and Jackie Anderson, Association member).

Before Records Kept:	Indians camped by the north outlet of Big Comfort where it again becomes the Sunrise River. Diggings show they gathered on the north side to hunt and fish.
Early 1850's	Road from St. Anthony to Taylors Falls built between the south shore of Big Comfort and north shore of Little Comfort (now Hwy. 8).
1855	Dr. John W. Comfort and nine other families arrive from Pennsylvania.
1855 to approx. 1910	Land around both lakes (Big & Little Comfort) used exclusively as farm and pasture.
1858	Wyoming Township organized.
1862 to 1866	Drought years. Lakes very low.
1868	St. Paul-Duluth Railroad completed. This ran through village of Wyoming and crossed tributaries of the lake.
1904	Judicial Ditch #1 constructed connecting with and straightening the Sunrise River. Judicial Ditch #1 crossed the Washington County border and drained areas from Forest Lake Township into the ditch and into Big Comfort.
1910	Cabins built on north shore of Big Comfort.
1917	Judicial Ditch #1 repaired and extended south into what is now the City of Forest Lake.
1940's	✓Maple Olson runs resort on SE corner of Big Comfort. ✓Nelson farm on Iris and crosses road to east side of Little Comfort. ✓Kendal's Resort is operated on east side of Big Comfort south of where 260th joins Pioneer Road.
1944	Chisago County portion of Judicial Ditch #1 repaired.
Early 1950's	✓Little Comfort was very low because of a beaver dam upstream. The dam was blown up an the lake level became very high and then leveled off. ✓Albert Olson bought the Nelson farm and built his home on the south side of Little Comfort where the Sunrise River enters the lake. He used the land around the lake as pasture.
1951	Regraded Hwy. 8 and put in a new culvert.
1952	Dennis Johnson lived in the house by the north shore of Little Comfort. The family rented boats.
1960's	The lake was so clear that Al Buchner and Sheriff's Patrol practiced diving in Big Comfort.
1962	Al Buchner buys Kendal's Resort.
1968	Aadland Shores developed on the east side of Big Comfort. Seven homes on the lake at Indian Trail on ½ acre lots.
1969	✓Al Buchner builds home on one acre of resort property. ✓Interstate 35 completed. Lots of fill dumped in Bixby Park (Forest Lake, Washington County) in connection with building this interstate. Judicial Ditch #1 runs through Bixby park and was affected by this.
Early 1970's	Homes built on east side of Little Comfort.

1971	Jacobsons bought land on south east side of Big Comfort (resort) and developed homes.
1977	Homes being built on West Comfort Drive. Home built on Itasca (south side of Little Comfort).
1978	More homes on north side of Big Comfort.
1980's	Shoreland lots rezoned to ½ acre.
1982	Roger Sinn reported the color of Big Comfort was black and fibrous dirt piled up on shore.
1983	More building on Little Comfort. 105 pound sturgeon found in Big Comfort.
1984	Archaeological Study done on north shore of Big Comfort before road change.
1985	✓260th on north side of Big Comfort moved behind cabins and homes. Culvert over Sunrise River redone. ✓New bridge and culverts on Hwy 98 and Pioneer Road. The openings were too large and the lake dropped 18" over night. Trap rock was put in by culvert and lake came back up.
1988	✓Congressional Study done on Chisago County Lakes. Comfort, Goose, and Fish Lakes were found to be the only totally swimmable lakes in the county. Currently Comfort is listed as supporting, but threatened. ✓Wyoming Township takes over zoning using an interim ordinance. ✓Resort on Pioneer and 260th sold and land developed.
1989	Comfort Lake Association formed. Secchi disc readings and water testing began by Association with assistance from Chisago County Water Plan.
Late 1980's	Pamida/Festival built in Forest Lake. This development drains into Judicial Ditch #1 and into Comfort Lake. This was built before many clean water regulations were in place.
Feb 1991	Wyoming Township adopts new ordinances. Lakeshore lots zoned one acre.
1991	✓DNR puts in Public Access (10 car) at north end of Big Comfort. ✓Anderson farm sold and developed six lake lots.
1991 to 1993	100 homes are built within watershed with black topped roads and individual septic systems and wells.
1992	Ditch on 260th redug and deepened on south side of road. Much run-off noted into lake - color change.
1992 to 1993	✓K-Mart built drainage (on ditch) connects to Big Comfort. ✓Culvert replaced in Elden Larsen farm crossing Sunrise River.
1993	Faircrest developed in Forest Lake, 31 homes on Judicial Ditch #1 (sewered).
1993	✓Still problems with run-off and silt from 260th ditch. Pecks yard full of silt and water. NSP re-sods and this helps to some extent. ✓Wal-Mart applies for Army Corps permit. Comfort Lake Association contacts developers, Army Corps, and City of Forest Lake. ✓Judicial Ditch Authority re-established after complaints of flooded farm fields near Shallow Pond. ✓ MPCA LAP study done on Comfort Lake.

1994	✓Two vacant parcels sold on west side of Big Comfort. 28 homes development. Six lots on lake and some on Judicial Ditch #1 (Sunrise River) one acre + lots, individual septic systems and wells. Road built over Sunrise River. ✓300 acres rezoned to one acre building sites between Comfort Lake and Goodview. This land is from ½ mile to three miles to the lake and much of it borders Judicial Ditch #1. ✓Comfort Lake Estates development begins with 30 home sites on southeast shore. East Comfort Drive is connected. ✓Walmart permit to fill 8 acres of wetland approved by Forest Lake. Wetland is part of JD 1 drainage area into Comfort Lake. ✓CLA request for EAW denied. ✓MPCA issues permit for construction of 11 acre replacement wetland on Elden Larsen farm in Wyoming Township. ✓Walmart site construction/filling of wetlands takes place from October 1994 to January 1995.
1994-Present	Perception of lake users is Big Comfort water quality has declined.
1995	April - MPCA begin intergovernmental meetings to address water quality/quantity issues which have arisen as a result of commercial development in Forest lake.
1995-1998	Area governmental units work toward joint watershed management thru expanded Forest Lake WMO.
1996	Chisago/Washington County Joint Ditch Authority votes to dissolve as land use has changed from farming to urban in nature.
1997	Clean Water Partnership project is initiated.
1998	WMO structure can not provide necessary operating framework for raising funds. Citizens petition to form Watershed District sent to BWSR.
1999	Comfort Lake/Forest Lake Watershed District formed.

I.1B. Why the Project Took Place

The current water quality and condition of Comfort Lake was classified by the 1994 MPCA Lake Assessment Program (LAP) Study as borderline mesotrophic-eutrophic for Big Comfort and eutrophic for Little Comfort. Secchi readings taken by the Lake Association for the past seven years have indicated a decline in the clarity of the lake and an increase in the phosphorus content of the lake (based on monitoring). Development within the lake's watershed has been intense for the past seven years. Forest Lake and Wyoming Township have seen rapid growth in commercial and residential developments.

The 1994 study concluded the lake is showing signs of suffering from the problems commonly associated with excessive nutrient loading from the lake's watershed. The LAP study concluded that Big Comfort and Little Comfort Lakes are sensitive to change in trophic status with relatively minor increases in the nutrient loading rates from any watershed or in-lake sources:

> "It is essential, therefore, that lake protection efforts be conveyed by all local government groups with land use/zoning authorities for Chisago and Washington Counties and to the area government units with responsibility for managing this resource." (LAP 1994).

Complaints by lake users and area residents deal primarily with degraded water clarity and late summer algae blooms (a first in 1996 for Big Comfort). Based on relationships between total phosphorus and hypolimnetic oxygen demand, phosphorus concentrations above 40 μg/l are undesirable for the maintenance of a walleye fishery. The lake's average summer phosphorus concentration was 55 μg/l on Little Comfort and 36 μg/l on Big Comfort in 1994.

The lake is at a critical point where proper management can reverse these trends before the lake degrades further.

I.1C. Project Goals and Objectives

A. Overall Resource Goal

The overall goal of this project was to develop a comprehensive Lake and Watershed Management Plan whose implementation will attain a lake system usable for a variety of recreation and environmental uses. The development of a watershed model capable of evaluating proposed watershed improvement projects and their impacts on the water quality of Comfort Lake is considered a key component of the watershed management plan.

B. Water Quality Characterization Goal

The goal of the diagnostic portion of the study was the development of accurate hydrologic and nutrient budgets for Comfort Lake and characterization of the lake's water quality. Internal and external sources of nutrients were evaluated.

C. Preliminary Quantitative Goals

The quantitative goal for the project is the formulation of a comprehensive Lake and Watershed Management Plan to attain an average summer total phosphorus concentration of 35 ug/l, or less, for both Big and Little Comfort. The goal is primarily based upon the following factors:

- The goal would achieve a water quality suitable for the maintenance of the lake's Bass-Panfish-Walleye fishery. According to the MPCA (1990), this concentration corresponds to the median for bass-panfish-walleye lakes in this region. Based on relationships between total phosphorus and hypolimnetic oxygen demand, phosphorus concentrations above 40 ug/l are undesirable for the maintenance of a walleye fishery.
- Achievement of this goal would maintain or improve the lake's use classification on Big Comfort and improve it to fully supporting on Little Comfort.

D. Information and Education Goals

The goal of the public information and education portion of the project is to create an awareness of water quality concerns among watershed residents and to teach changes in behavioral and land management patterns. The primary goal is the development of tools to help watershed residents reduce phosphorus loading to the lake. One such tool is a newsletter that encourages use of low phosphorus fertilizers, septic system maintenance, lawn management practices, BMP for developers and aqua-scaping for lake shore owners.

E. Fishery and Wildlife Goals

A fishery goal is to maintain Comfort Lake as a viable sport fishery and a wildlife goal is to set up a program to protect wildlife habitat. Comfort Lake has been home to many loons, river otters, beavers, turtles, spring and fall migrating duck and swan populations and eagles.

F. Regional Water Quality Goals

To maintain Comfort Lake as a fully swimmable lake, to improve Comfort to that status and to maintain downstream quality.

I.1D. Who Was Involved in Carrying Out the Project

Jackie Anderson
Project Representative, Wyoming Township

Diana McEvoy
Comfort Lake Association

Steve Schriber
Comfort Lake Volunteer

Mayor Raymond Daninger
City of Forest Lake

Mary Darragh Schmitz
Chisago County Water Plan Coordinator

Mike Mueller
MnDNR Hydrologist

Shannon Lotthammer
MPCA - Project Manager

Celine Lyman
MPCA - Project Manager

Norma Olson
Town Clerk

Lisa Hughs
Zoning Administrator

Nancy Blomberg
Town Secretary

Steve McComas, Blue Water Science; **Dave Schuler**, Schuler Environ. Engineering, **Eco-Agri Laboratories**, Willmar and **Minnesota Department of Health** conducted lab analysis

I.1E. Project Costs by Program Element

Project budget and costs by program element are shown in Table 2.

Table 2. Project budget and project costs.

	Project Budget	Total Spent	Amount Remaining of Budget
1. Development of Project Plans	**1,000**	3,445	<2,445>
2. Lake Monitoring/Lab Analysis (labor, equip, travel)	**8,321**	8,321	0
Lab analysis	**4,700**	4,700	0
3. Stream Monitoring/Lab Analysis (labor, equip, travel)	**8,500**	8,500	0
Lab analysis	**1,500**	1,765	<265>
4. Water Quality Modeling, Data Analysis and Assessment	**3,600**	3,600	0
5. Watershed Assessment	**2,000**	3,300	<1,300>
6. Implementation Plan and Report Preparation	**6,000**	6,857	<857>
7. Information and Education Program (newsletter and lake mag)	**3,300**	3,300	0
8. Project Management and Coordination	**2,000**	3,726	<1,726>
subtotal	**$40,921**	**$47,514**	**<$6,593>**
9. Central Minnesota Initiative Grant Element			
9.1. Add 4th stream monitoring site	**3,500**	3,500	0
9.2. Test incoming groundwater	**300**	300	0
9.3. Onsite system evaluation/effluent testing	**1,200**	1,200	0
9.4. Questionnaire/watershed manual	**5,000**	5,000	0
subtotal	**$10,000**	**$10,000**	**$0**
TOTAL	**$50,921**	**$57,514**	**<$6,593>**

I.1F. Project Milestones

A project milestone schedule is shown in Table 3.

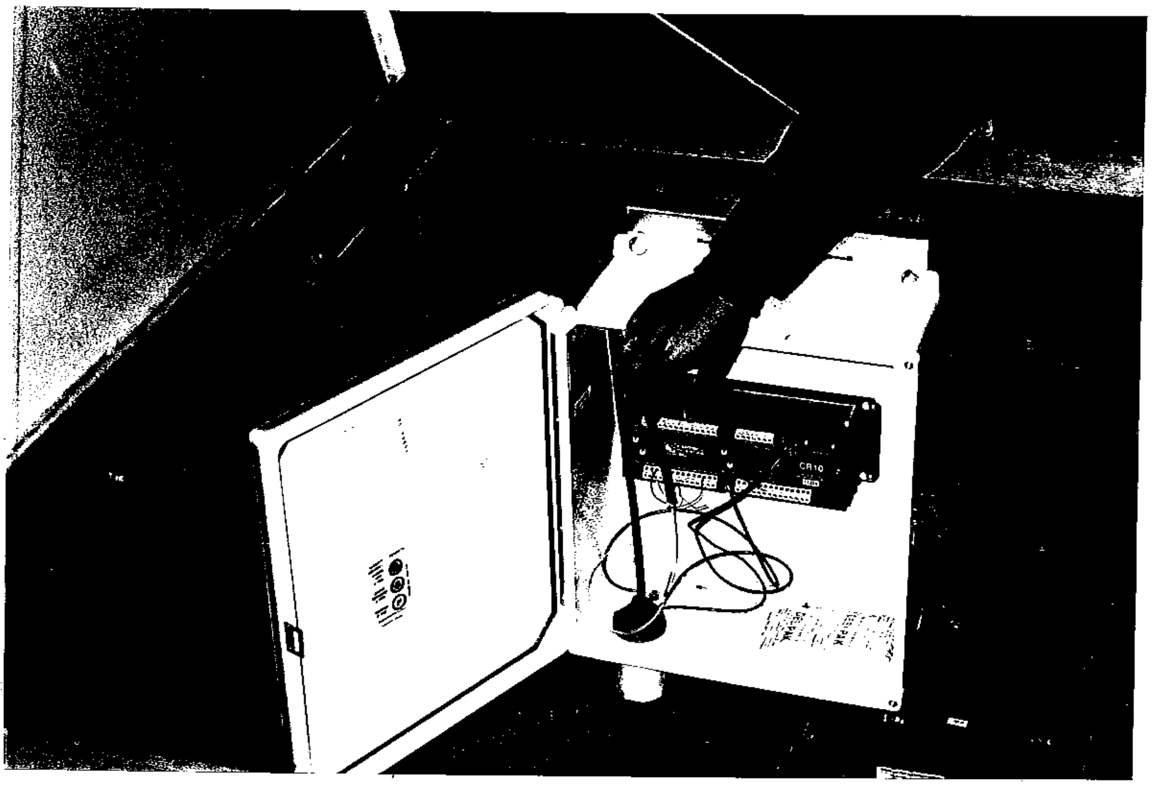
Table 3. Project milestone schedule.

TIME FRAME				
Program Element	**Start Date**	**Estimated End Date**	**Actual End Date**	**Responsible Groups**
1. Develop project work plan	9/97	5/98	9/99	Steering committee & Consultant
2. Lake monitoring/lab analysis	9/97	10/98	8/99	Volunteers, Consultant, MPCA, DNR
3. Stream monitoring/lab analysis Assn., volunteers	9/97	10/98	8/99	MPCA, DNR, Consultant, Lake Assn., Volunteers
4. Water quality modeling and data analysis	12/97	3/99	3/00	Consultant, MPCA, DNR
5. Watershed assessment	12/97	4/99	3/00	County, DNR, Consultant
6. Report preparation	ongoing	3/2000	3/00	Steering committee, Consultant, MPCA, Wyoming Township
7. Volunteer training and education program	9/97	4/2000	1/00	Steering committee, Wyoming Township, Consultant, Joint County WMO, Lake Assn.
8. Fiscal project management	9/97	4/2000	5/00	Wyoming Township, Steering committee, MPCA, Consultant
9. Central Minnesota Initiative Grant	6/98	12/99	12/99	Wyoming Township, Steering committee, MPCA, Consultant

II. Diagnostic Study

II.1. Methods

Appendix 1 describes the methods and quality control programs employed for this Clean Water Partnership Project for water quality sampling and lab analysis.



Flow monitoring recording station at Site 5.

II.2. Results

II.2A. Watershed Assessment

Glacial Geology

As glaciers advanced across Minnesota they carried along material ranging from huge boulders to small sand particles. As the glaciers melted they left behind the materials that had been carried along. This material is known as drift. The Comfort Lake basin is located in a ground moraine from the Grantsburg Lobe (Figure 2)

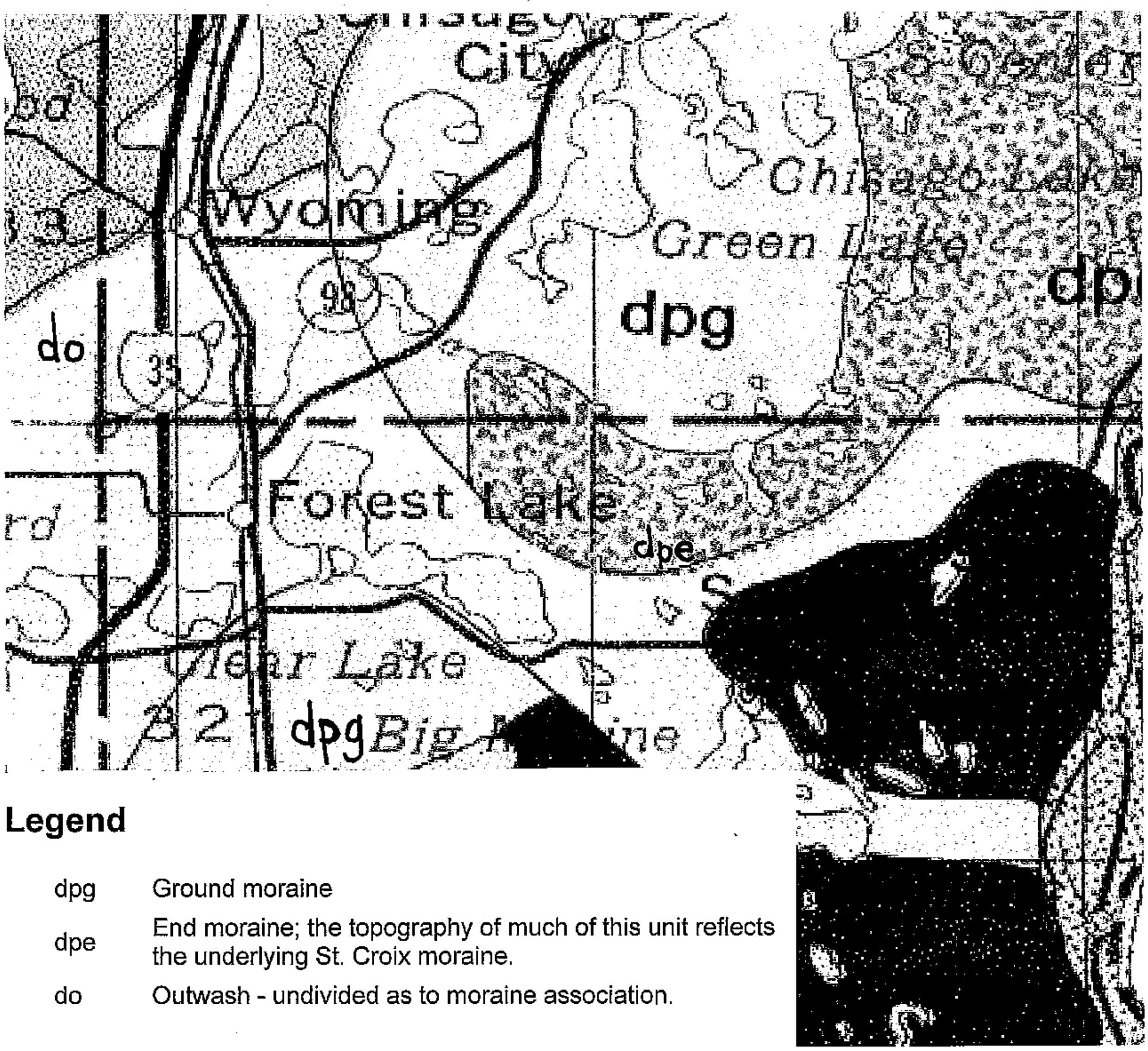


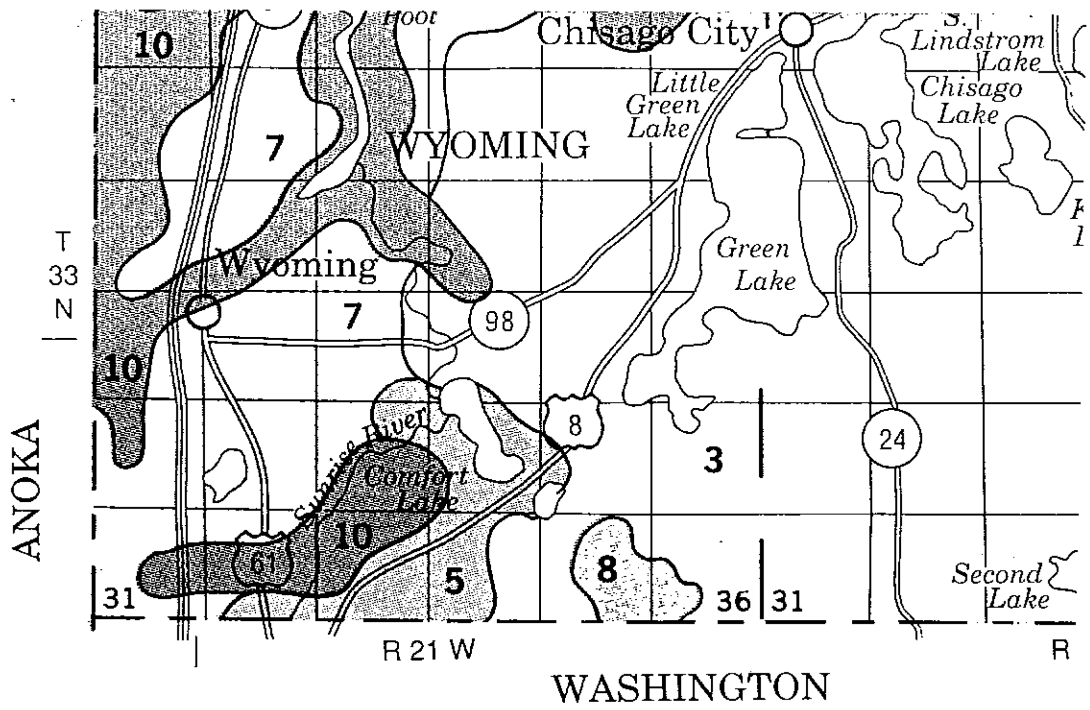
Figure 2. Soils of Comfort Lake.

Soils

The soils in the Comfort Lake watershed range from excessively drained to poorly drained soils. There are three different soil associations represented in the Comfort Lake watershed: Nebish-Talmoon; Braham-Blomford-Eckvoll; Mahtomedi-Pomroy.

The majority of the watershed is the Nebish-Talmoon Association (Figure 3) the soils are represented by well drained and poorly drained, loamy soils. The other association soils are moderately well drained to poorly drained, sandy soils (Brahan-Blomford-Eckvoll Association) and excessively drained and well drained, sandy soils (Mahtomedi-Pomroy Association).

A map of soil series is shown in Figure 4. Many of the soils are rated as moderate to severe for septic tank/soil absorption systems due to wetness, poor filter, and seepage caused by slow percs. These soils may not treat wastewater as well as a more loamy soil.



Legend

Soil Type	
3	Nebish-Talmoon association
5	Braham-Blomford-Eckvolt association
8	Mahtomedi-Pomroy association
10	Seeleyville-Markey association

Figure 3. Soil associations for the Comfort Lake watershed.

Figure 4. Representative soils around Comfort Lake.

Table 4. Characteristics of soils series for soils in the Chisago and Washington Counties watershed corn production is from Table 16, % clay, organic matter, and pH are from Table 15, and septic tank absorption field descriptions are from Table 11.

Soil Number and Name		Characteristics				
		Corn Production (bushel/ac)	Clay % (A horizon)	Organic Matter (%)	Soil Reaction pH	Septic Tank Absorption
Site 1						
158B	Zimmerman loamy fine sand	50	2-10	0.5-1	5.1-6.5	Severe-poor filter
158C	Zimmerman loamy fine sand	--	2-10	0.5-1	5.1-6.5	Severe-poor filter
159B	Anoka loamy very fine sand	75	2-10	0.5-1	5.6-6.5	Slight
161	Isanti loamy fine sand	45	2-10	3-15	5.1-6.5	Severe-wet, poor filter
162	Lino loamy fine sand	70	2-10	0.5-2	5.1-6.0	Severe-wet, poor filter
540	Seelyeville muck	50	--	55-85	4.5-7.8	Severe-ponding
543	Markey muck	50	--	55-85	5.6-7.8	Severe-ponding, percs slowly
1055	Aquolls and Histosols	—	--	—	—	--
Site 2						
75	Bluffton loam	75	14-25	3-7	5.6-6.5	Severe-ponding, percs slowly
113	Webster loam	85	20-36	6-7	6.6-7.3	Severe
123	Dundas fine sandy loam	85	5-15	2-4	5.6-7.3	Severe
158B	Zimmerman loamy fine sand	50	2-10	0.5-1	4.5-6.5	Severe-poor filter
158C	Zimmerman loamy fine sand	45				Moderate
161	Isanti loamy fine sand	55	2-10	3-15	4.5-6.5	Severe-wet, poor filter
162	Lino loamy fine sand	60	2-10	0.5-1	4.5-6.0	Severe-wet, poor filter
169B	Braham loamy fine sand	60	2-10	0.5-2	5.6-7.3	Moderate
170	Blomford loamy fine sand	60	2-10	1-4	5.1-7.3	Severe-wet
225	Nessel fine sandy loam	85	5-15	2-3	5.6-7.3	Severe-wet
481	Kratka fine sandy loam	55	5-15	1-2	5.6-7.8	Severe-floods, wet, percs slowly
540	Seelyeville muck	--	--	>25	5.6-7.3	Severe-pondings
541	Rifle muck	--	--	>25	5.6-7.3	Severe-floods, wet
543	Markey muck	50	--	55-85	5.6-7.8	Severe-pondings, percs slowly
544	Cathro muck	75	--	60-85	5.6-7.8	Severe-pondings, percs slowly
859B	Urban land, Zimmerman complex	--	2-10	0.5-1	4.5-6.5	Slight
860C	Urban land, Hayden-Kingsley complex	--	3-15	0.5-4	5.6-7.3	Mod-Severe-percs slowly, slope
862	Urban land, Dundas complex	--	5-15	2-4	5.6-7.3	Severe-percs slowly, wet
1027	Udorthents	—	--	—	—	--
1040	Udorthents	—	--	—	—	--
1055	Aquolls and Histosols	—	--	—	—	--
Site 5						
40B	Nebish loam	110	5-20	1-2	6.1-7.3	Moderate
40C	Nebish loam	90	5-20	1-2	6.1-7.3	Moderate
40D	Nebish loam	--	5-20	1-2	6.1-7.3	Severe-slope
75	Bluffton loam	80	14-25	3-7	5.6-6.5	Severe-ponding, percs slowly
113	Webster loam	85	20-36	6-7	6.6-7.3	Severe-wet, percs slowly
158B	Zimmerman loamy fine sand	50	2-10	0.5-1	5.1-6.5	Severe-poor filter
162	Lino loamy fine sand	70	2-10	0.5-2	5.1-6.0	Severe-wet, poor filter
169B	Braham loamy fine sand	70	2-8	0.5-2	5.6-7.3	Moderate
169C	Braham loamy find sand	60	2-8	0.5-2	5.6-7.3	Moderate
170	Blomford loamy fine sand	60	2-10	1-4	5.1-7.3	Severe-wet
346	Talmoon loam	90	8-20	2-4	5.1-7.3	Severe-wet, percs slowly
540	Seelyeville muck	50	--	55-85	4.5-7.8	Severe-ponding
543	Markey muck	50	--	55-85	5.6-7.8	Severe-ponding, percs slowly
544	Cathro muck	50	--	55-85	4.5-7.8	Severe-ponding, percs slowly
678	Beltrami loam, thick solumn	115	6-18	2-4	6.1-7.3	Severe-wet
722	Blomford loamy sand, lacustrine substratum	65	2-8	1-4	5.1-7.3	Severe-seepage, poor filter
726	Kratka loamy fine sand, thick solumn	--	2-10	1-3	6.1-7.3	Severe-ponding, percs slowly, poor filter
1033	Udifluvents	--	—	—	--	—
1040	Udorthents	--	—	—	--	—

Wetlands

Wetlands and other lakes cover approximately 7,350 acres of the Comfort Lake watershed based on the National Wetland Inventory map (Figure 5). The majority of the wetlands are found within the Big Comfort watershed (5,850 acres).

Over 25% of the watershed area in the Comfort Lake watershed is composed of wetlands. A breakdown of wetlands by subwatershed is shown in Table 5.

Table 5. Wetland acreage by subwatershed.

Little Comfort Subwatersheds	Subwatershed (acres)	Wetlands & Lakes* within Subwatershed (acres)	Percent Wetlands & Lakes in Subwatershed (%)
Bone Lake	5,177	1,105	21
School Lake	4,164	1,019	24
Total Subwatersheds (Station 3)	9,341	2,124	23
Direct Drainage	200	51	26
Little Comfort Watershed	9,541	2,175	23

*excluding Little Comfort Lake

Big Comfort Subwatersheds	Subwatershed* (acres)	Wetlands & Lakes* within Subwatershed (acres)	Percent Wetlands & Lakes in Subwatershed (%)
1	1,357	424	31
2	1,641	613	37
5	1,861	680	37
4. Forest Lake	6,535	2,600	60
Total Subwatersheds 1+2+4+5	11,394	4,317	47
Little Comfort Lake	9,578*	2,212	23
Direct Drainage	603	74	12
Big Comfort Watershed	21,575	4,886	25

*including Little Comfort Lake

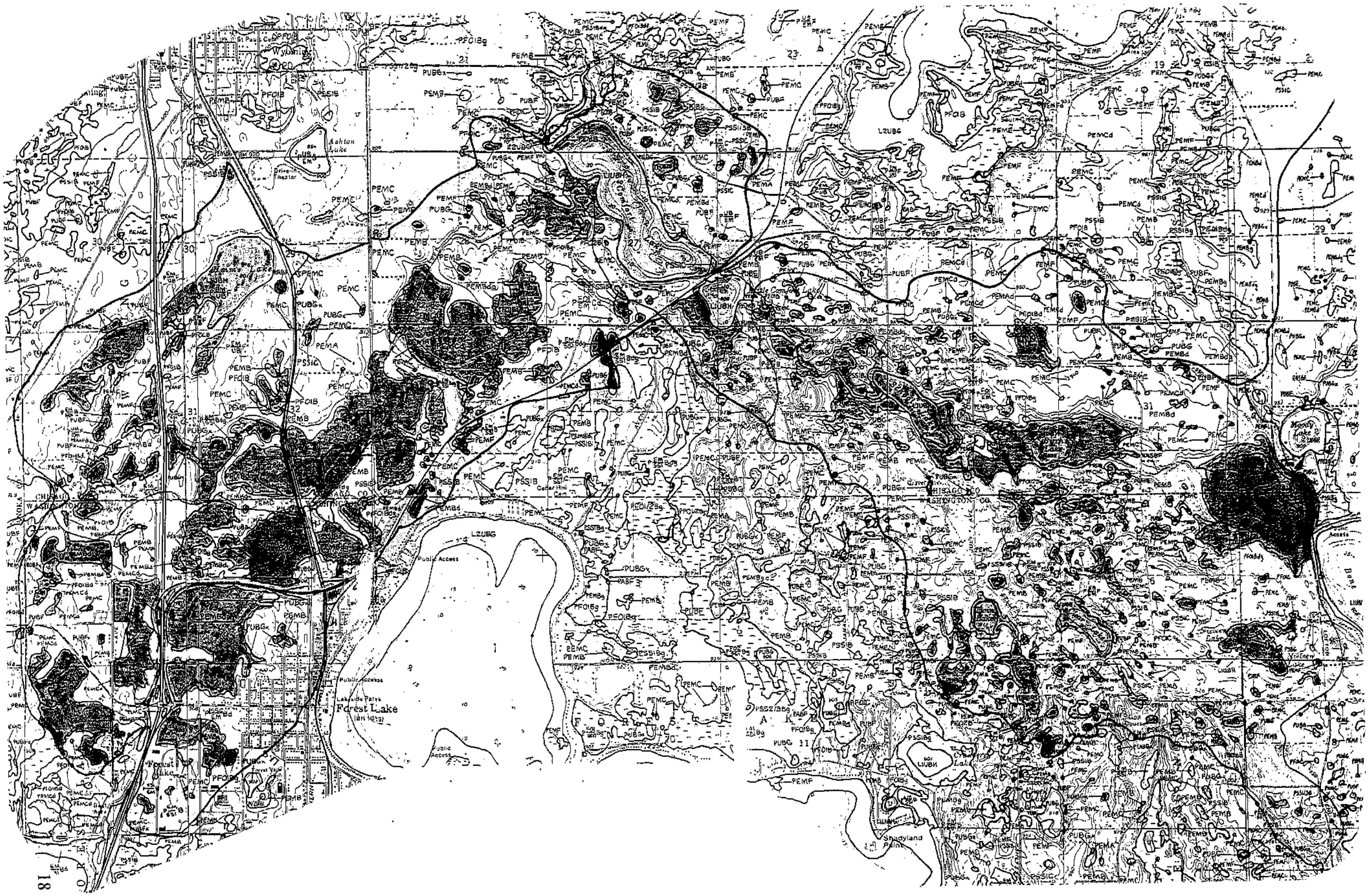


Figure 5. Wetlands in several subwatershed in the Comfort Lake watershed (source: Natural Wetland Inventory).

Land Use

Big Comfort and Little Comfort Lakes are located in Chisago County. They have surface areas of 219 and 37 acres, respectively. The total watershed for these lakes is about 21.2 square miles. The watershed includes Forest Lake which outlets to the Sunrise River and flows north to Big Comfort and Joint Ditch #1 which begins at the I-35, Broadway Avenue interchange in Forest Lake and flows north to connect to the Sunrise River coming out of Forest Lake. A land use summary is shown in Table 6.

Table 6. Land use in the Comfort Lake watershed.

Land Use (%)	Big/Little Comfort Direct Drainage	Total Watershed	North Central Hardwood Forest Ecoregion*
Forest	9%	16%	6-25%
Water & Marsh	39%	49%	14-30%
Pasture & Open	7%	6%	11-25%
Cultivated	27%	14%	22-50%
Urban	18%	25%	2-9%

* Derived from Heiskary and Wilson (1990) Table 6.

Wyoming Township has had substantial growth in one acre residential home sites within the watershed of Big Comfort in the decade form 1990-2000. Housing units grew from 934 in 1990 to 1,644 in 2000. Of those 730 new homes, 650 are in the Comfort Lake watershed. All are on individual septic systems and wells (see chart of permits).

The City of Forest Lake has seen a near 100% conversion of open fields to commercial property at the 35W/Broadway Intersection. All land drains into the Sunrise River (JD1). In addition the industrial avenue along 12th St and 3rd Ave was connected to the storm sewer system during the Walmart construction in 1995. The most recent storm sewer amp available for the City is 1980.

Forest Lake adopted the MPCA stormwater best management practices ordinance in 1996-97.

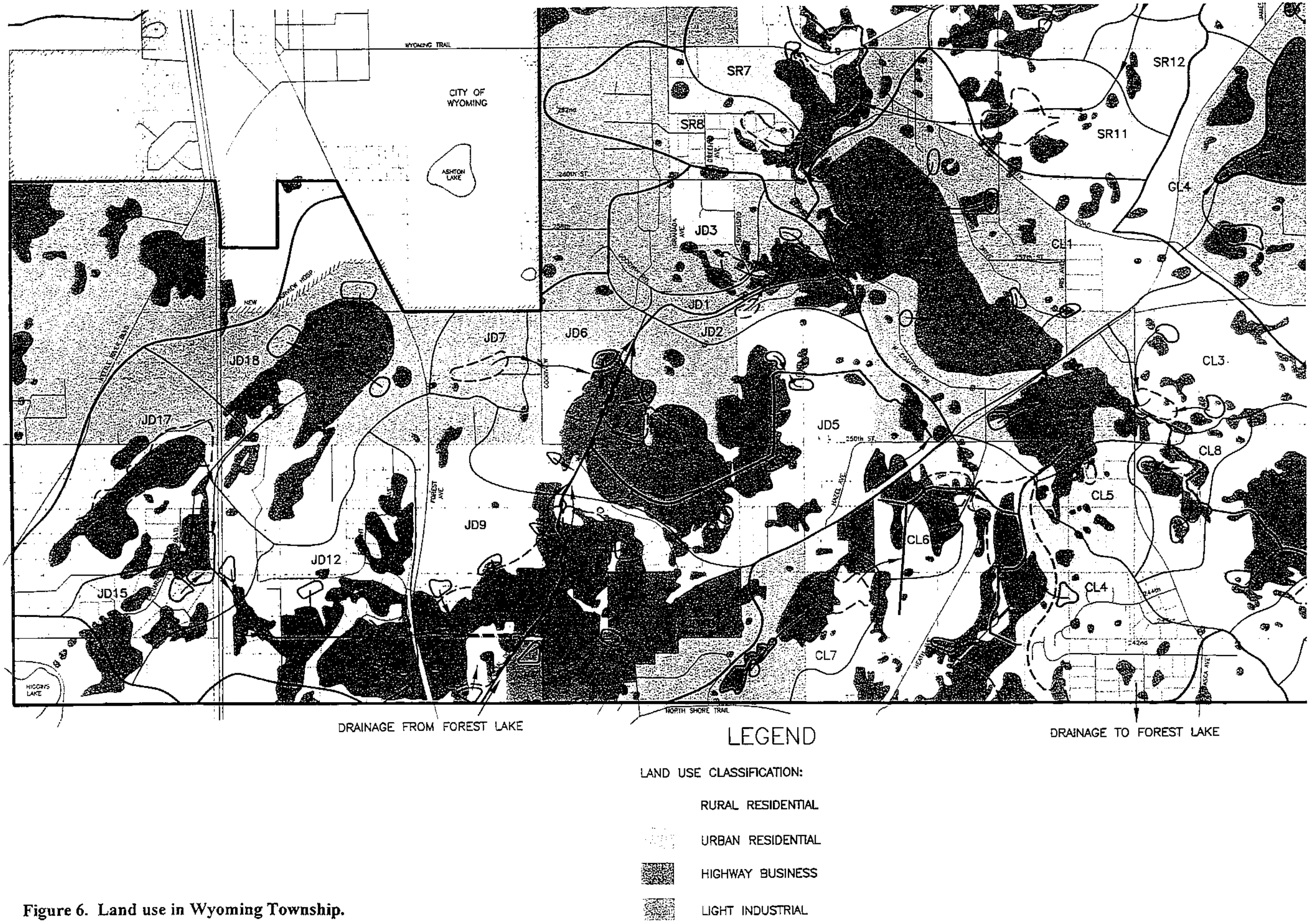


Figure 6. Land use in Wyoming Township.

Town of Wyoming Building Report
2000

Total Building Permits - 198
Total Valuation of Building Permits - $10,154,950

New Single Family Dwellings - 20
Value of Single Family Dwellings – $4,243,000

Commercial Permits – 9
Value of Commercial Permits – $4,104,000

"Other" Building Permits – 169
Value of "Other" Permits – $1,807,950

New Septic Permits – 18
Replacement Septic Permits – 37
Extend Septic System Permits – 2
Repair Septic System Permits - 2
Total Septic Permits – 59

Total Heating Permits – 66
Total Plumbing Permits – 44

Total Permits Issued by Building Dept. - 367

Building Permit Revenue Summary

Year	Building Permits	Total Revenue
1995	184	$86,044.21
1996	178	$154,147.25
1997	163	$183,756.15
1998	218	$226,437.66
1999	213	$197,981.88
2000	**198**	**$142,626.36**

Building Permits – 1999

Single Family Dwellings	20
Additions	28
Decks	45
"Basement" Finish	8
Detached Accessory	40
Reside/Reroof	27
Remodel	5
Manufactured Homes (Trailer)	4
Pools	5
Demolition	1
Window Replacement	5
Move Building	1
Commercial	10
Total	
Projects	**206**
Permits	**198**

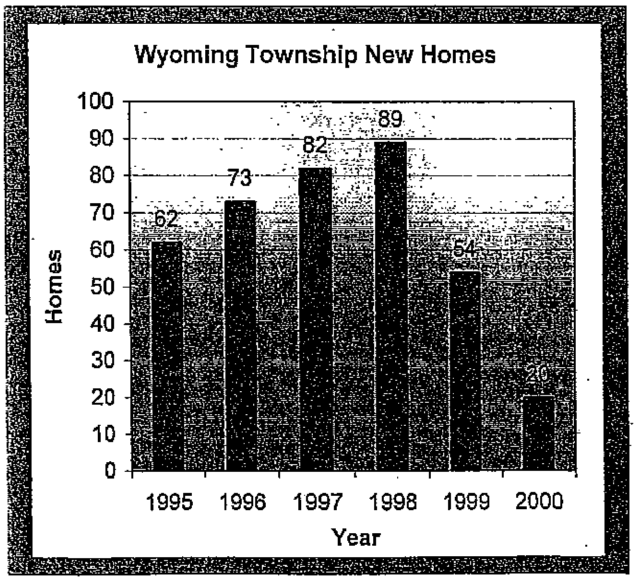


Figure 7. Representative housing density in Wyoming Township.

Section 6 89-0 90-0 91-0 92-0 93-0 94-0 95-0 96-0 97-0 98-0 99-0 00-0 total homes-0	**Section 5** 89-1 90-0 91-0 92-0 93-3 94-2 95-0 96-0 97-0 98-0 99-0 00-0 total homes-6	**Section 4** 89-0 90-0 91-0 92-1 93-0 94-0 95-1 96-0 97-1 98-0 99-0 00-0 total homes-3	**Section 3** 89-1 90-0 91-1 92-0 93-0 94-0 95-3 96-6 97-23 98-4 99-0 00-0 total homes-38	**Section 2** 89-0 90-1 91-0 92-0 93-0 94-1 95-1 96-0 97-0 98-0 99-0 00-0 total homes-3	**Section 1** 89-0 90-0 91-0 92-0 93-0 94-0 95-0 96-0 97-0 98-0 99-0 00-0 total homes-0
Section 7 89-0 90-0 91-0 92-0 93-0 94-0 95-0 96-0 97-0 98-0 99-0 00-0 total homes-0	**Section 8** 89-0 90-0 91-0 92-0 93-0 94-0 95-0 96-1 97-1 98-2 99-3 00-0 total homes-7	**Section 9** 89-0 90-0 91-0 92-0 93-0 94-0 95-0 96-0 97-0 98-0 99-0 00-1 total homes-1	**Section 10** 89-0 90-0 91-0 92-0 93-0 94-0 95-0 96-0 97-0 98-0 99-1 00-0 total homes-1	**Section 11** 89-1 90-0 91-1 92-0 93-1 94-1 95-3 96-1 97-0 98-0 99-1 00-0 total homes-9	**Section 12** 89-2 90-0 91-4 92-0 93-3 94-4 95-2 96-4 97-3 98-1 99-1 00-0 total homes-24
Section 18 89-0 90-0 91-0 92-2 93-0 94-0 95-0 96-0 97-0 98-0 99-0 00-0 total homes-2	**Section 17** 89-0 90-0 91-3 92-9 93-7 94-5 95-11 96-13 97-1 98-0 99-0 00-0 total homes-49	**Section 16** 89-0 90-0 91-0 92-1 93-1 94-0 95-0 96-0 97-4 98-0 99-0 00-0 total homes-6	**Section 15** 89-0 90-0 91-0 92-1 93-0 94-0 95-0 96-0 97-0 98-0 99-0 00-1 total homes-2	**Section 14** 89-0 90-0 91-0 92-0 93-1 94-1 95-0 96-0 97-1 98-8 99-8 00-1 total homes-20	**Section 13** 89-3 90-1 91-1 92-1 93-1 94-0 95-0 96-1 97-3 98-6 99-4 00-1 total homes-22
Section 19 89-0 90-0 91-0 92-0 93-0 94-0 95-0 96-0 97-0 98-0 99-0 00-0 total homes-0	**Section 20** **CITY** **OF** **WYOMING**	**Section 21** 89-0 90-1 91-2 92-15 93-32 94-21 95-7 96-3 97-9 98-19 99-4 00-0 total homes-113	**Section 22** 89-1 90-2 91-2 92-3 93-3 94-3 95-0 96-0 97-0 98-1 99-0 00-1 total homes-16	**Section 23** 89-0 90-0 91-0 92-0 93-2 94-5 95-1 96-0 97-0 98-0 99-2 00-0 total homes-10	**Section 24** 89-2 90-4 91-8 92-1 93-5 94-1 95-1 96-3 97-1 98-1 99-0 00-0 total homes-27
Section 30 89-1 90-5 91-15 92-12 93-10 94-11 95-5 96-5 97-1 98-0 99-0 00-0 total homes-65	**Section 29** 89-2 90-1 91-1 92-2 93-0 94-0 95-0 96-0 97-0 98-0 99-0 00-0 total homes-6	**Section 28** 89-11 90-17 91-17 92-21 93-15 94-10 95-13 96-8 97-10 98-37 99-19 00-6 total homes-184	**Section 27** 89-4 90-5 91-4 92-3 93-8 94-9 95-5 96-8 97-9 98-5 99-5 00-5 total homes-70	**Section 26** 89-1 90-2 91-1 92-2 93-1 94-1 95-0 96-1 97-0 98-0 99-1 00-0 total homes-10	**Section 25** 89-3 90-2 91-1 92-5 93-3 94-2 95-1 96-0 97-0 98-0 99-0 00-0 total homes-17
Section 31 89-4 90-14 91-8 92-9 93-7 94-5 95-2 96-7 97-0 98-0 99-0 00-0 total homes-56	**Section 32** 89-0 90-2 91-5 92-11 93-11 94-11 95-2 96-1 97-6 98-0 99-0 00-1 total homes-50	**Section 33** 89-6 90-2 91-3 92-2 93-0 94-0 95-0 96-1 97-2 98-1 99-0 00-0 total homes-17	**Section 34** 89-2 90-1 91-1 92-2 93-2 94-2 95-1 96-4 97-2 98-1 99-2 00-0 total homes-19	**Section 35** 89-3 90-0 91-4 92-7 93-9 94-5 95-4 96-6 97-4 98-2 99-3 00-1 total homes-48	**Section 36** 89-0 90-1 91-0 92-2 93-0 94-0 95-0 96-0 97-2 98-1 99-0 00-2 total homes-8

2000
New Homes in
Wyoming Township
by Section

Building Permits
Increase/Decrease
1999-2000

Single Family Dwellings	–36
Additions	+8
Decks	+4
"Basement" Finish	+2
Detached Accessory	–7
Reside/Reroof	+5
Remodel	0
Manufactured Homes (Trailer)	–2
Pools	+3
Commercial	+2
Demolition	+4

Figure 7b. Representative housing density in Wyoming Township.

Water Supplies: Drinking water around Big and Little Comfort Lakes is supplied by individual wells. In Wyoming Township, the low density residential housing units also use individual drinking water wells.

Point Sources of Pollution: Examples of point sources are industrial or wastewater treatment plants that discharge from the end of pipes. No point sources of pollution are known in this watershed.

Septic Systems: There are no septage dumping sites in the watershed. Forest Lake and Forest Lake Township are served by the MUSA Metro Line. There are no feedlots in the Big Comfort Lake watershed and only 4 working farms. There was no evidence of excessive nutrient loading from these farms during the study.

Stormwater Management: Wyoming Township commenced a water quality/quantity study by an engineering firm in 1995. The resulting Surface Water Management Plan was adopted in 1997 to guide development within the Town and control water runoff. With the large lots and natural swales in addition to the storm water ponding, stormwater management practices are in place. In the City of Forest Lake, the storm sewer plan has not been updated since 1980. The development of commercial land 35W/Broadway interchange to nearly 100% impervious surface has increased runoff.

Economic Status of Comfort Lake and Surrounding Area: Property values on Comfort Lake are shown below. Property values represent 8% of the Township value (Table 7).

Table 7. Year 2000 Property values on Comfort Lake*

	Estimated Market Value	Taxable Market Value	Tax Capacity	Total Parcels	Average Parcel
	WYOMING TOWNSHIP				
	$258,065,300.00	$249,704,200.00	$3,398,212.00	--	--
	VALUE OF PROPERTY AROUND COMFORT LAKES				
Parcels	$4,834,200.00	$4,795,200.00	$64,814.0	40	$119,880.00
Lake Lots	$12,258,600.00	$12,194,600.00	$167,537.00	83	$149,922.89
Bridgewater	$2,948,400.00	$2,906,700.00	$39,070.00	26	$111,796.15
Total	$20,041,200.00	$19,896,500.00	$271,421.00	149	$133,533.56
	PERCENT OF TOWNSHIP VALUE				
	8%	8%	8%	--	--

* includes all property around Big and Little Comfort, Bridgewater, and Comfort Lake Estates.

II.2B. Shoreland Assessment

The shoreland area encompasses three components: the upland fringe, the shoreline, and shallow water area by the shore. Several projects were conducted in the shoreland including a shoreland inventory, shallow water conductivity survey, and an on-site wastewater treatment system survey.

Shoreland Inventory: A photographic inventory of the Big Comfort Lake shoreline was conducted from October 9 through November 2, 1998. The objectives of the survey were to characterize existing shoreland conditions to serve as a benchmark for future comparisons.

For each photograph we looked at the shoreline and the upland condition. Our criteria for a natural upland was the presence of 50% native vegetation in the understory.

Results of the inventory are shown in Table 8. Based on our subjective criteria over 50% of the parcels in the Big Comfort Lake shoreland area meet the natural rankings for shorelines and upland areas. For a lake in the urban/rural transition zone this is about normal. However in the next 10 years proactive volunteer native landscaping could maintain existing conditions and improve other parcels.

A map shows segments of Big Comfort shorelines have up to 90% natural conditions. The north east end has less than 30% (Figure 8).

Table 8. Summary of buffer and upland conditions in the shoreland area of Big Comfort Lake. Approximately 100 parcels were examined.

	Percent
Shorelines with >50% natural buffer	61%
Upland areas >50% natural conditions	62%
Lots with both natural buffers and upland conditions	52%
Lots with rip-rap or retaining walls.	12%

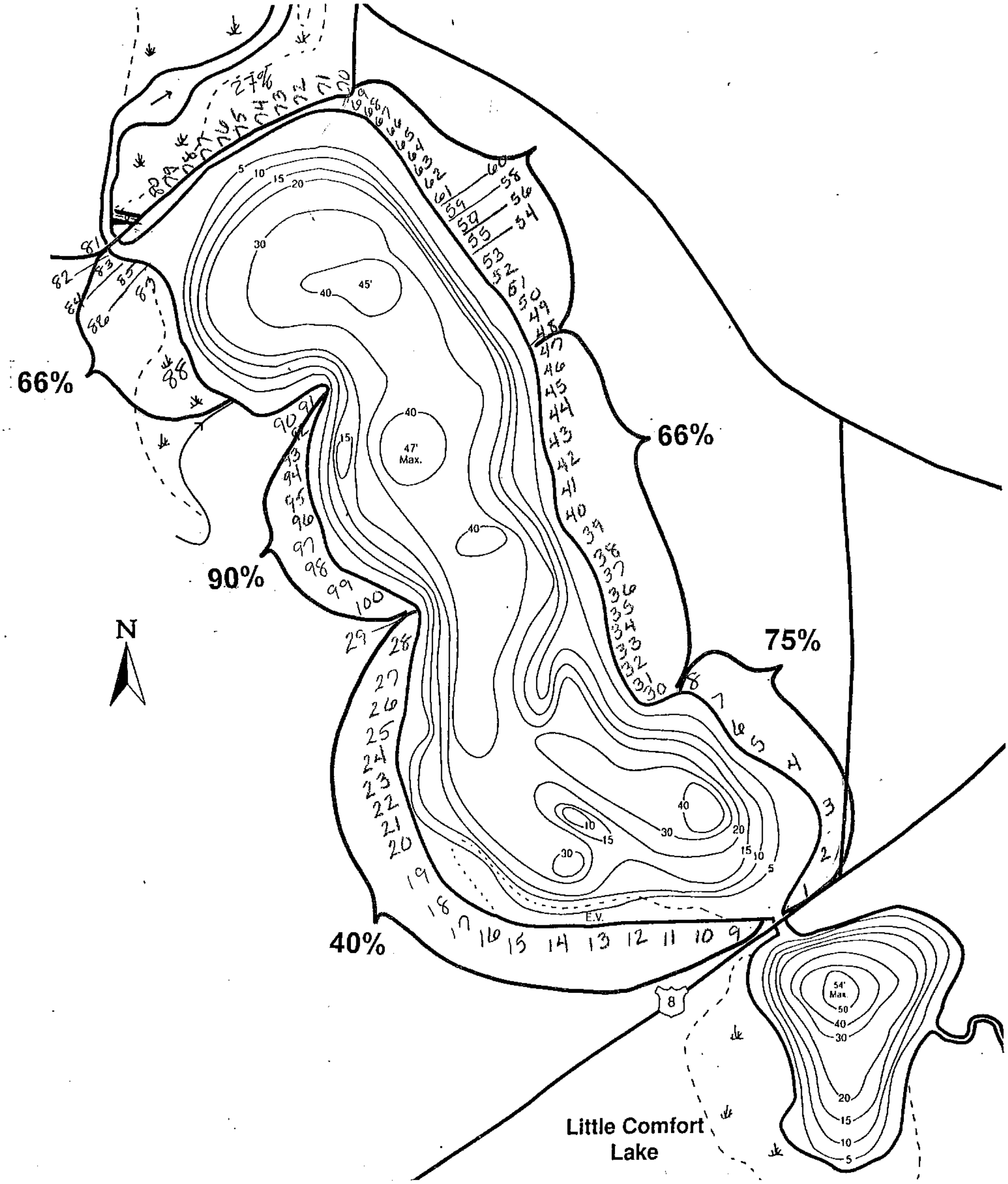


Figure 8. The percent of parcels meeting natural shoreline criteria for shoreland segments on Big Comfort Lake. Survey was conducted from October 9 - November 2, 1998.

On-Site Wastewater Treatment Systems

Currently all homes around Comfort Lake have onsite treatment systems. Results of homeowner surveys conducted in 1994 and 1999 found that 80% and 87%, respectively, of the septic systems are less than 20 years old with 50% less than 10 years old. The most common system employed around the lake is septic tanks with drainage fields. Results of these two surveys can be found in Tables 9 and 10.

A septic leachate survey that was conducted on November 2, 1998 (Figure 9) theoretically could detect the presence of septic drainfield leachate if elevated conductivity readings were detected. We found five areas where groundwater may be entering Big Comfort Lake. The inflow conductivity was not high enough to be septic effluent and we suspect it is only groundwater. A soils map for the area shows wetlands behind 3 of the inflow areas (Figure 10). Big Comfort has mostly adequate soils for on-site systems, and Little Comfort Lake does not.

In 1996, a Township ordinance was passed for requiring a minimum drainfield set back of 75 feet from the lake.

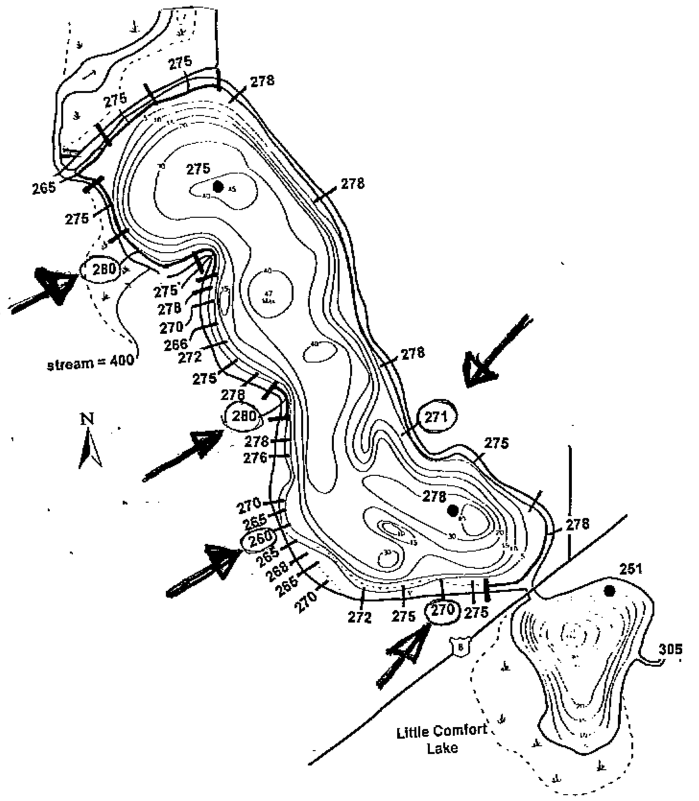


Figure 9. Septic leachate survey conducted on Comfort Lake on November 2, 1998. Background conductivity was 275 uhmos and 278 uhmos at the north and south ends of Big Comfort respectivefully. There are five locations that may have groundwater flowing into the lake shown with the circled numbers.

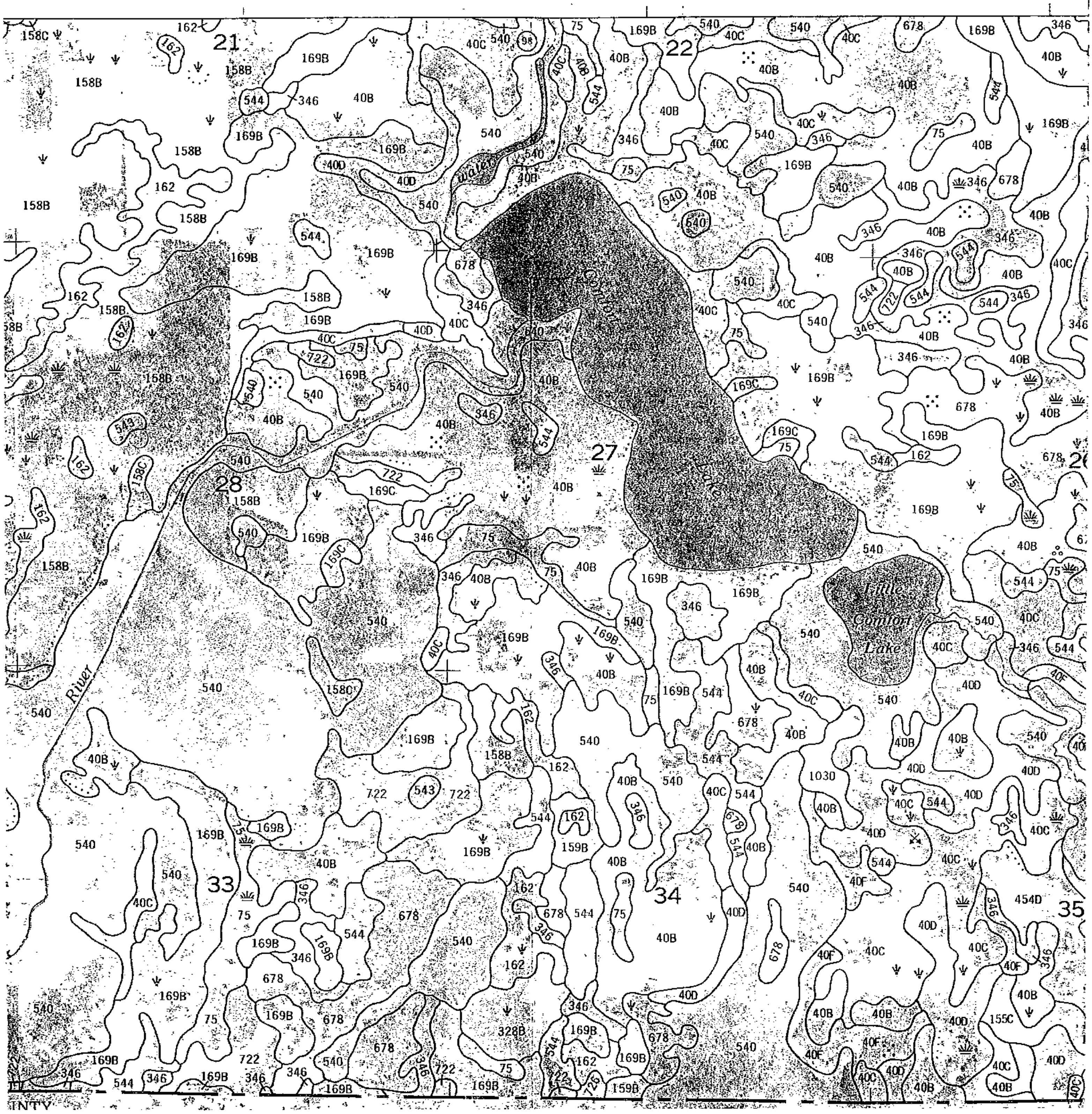


Figure 10. Some soils around Comfort Lake may be problematic for on-site systems. These soil series are 540, 678, 346, and 75. Soil limitations are due to slow infiltration and ponding tendencies (see Table 4 for other soil series information).

Table 9. Big Comfort Lake, septic system survey results for 1994 (based on 59 returns out of 100 homes).

	Big Comfort		Little Comfort	
TYPE OF DWELLING	No. of Response	Percent	No. of Response	Percent
Seasonal	3	5	--	--
Year Round	56	95	16	100
Year round, but not a primary residence	--	--	--	--
SYSTEM AGES (years)	No. of Response	Percent	No. of Response	Percent
0-5	20	34	5	31
6-10	15	26	3	19
11-15	8	14	3	19
16-20	4	7	3	19
21-25	4	7	1	6
26-30	3	5	--	--
30+	3	5	1	6
unknown	1	1	--	--
lot only - no building	1	1	--	--
DISTANCE FROM LAKE TO CLOSEST POINT OF SYSTEM (feet)	No. of Responses	Percent	No. of Response	Percent
0-50	4	7	--	--
51-100	21	36	1	6
101-150	12	20	2	12
151-200	9	15	3	19
201-250	3	5	4	25
251+	6	10	--	--
no response	4	7	--	--
SYSTEM TYPES	No. of Response	Percent	No. of Response	Percent
Septic tank - drainfield	49	84	15	94
Septic tank - drywell	1	1	--	--
Shared septic tank - drainfield	—	--	—	—
Cesspool	--	--	--	--
Holding tank	--	--	1	6
Privy	3	5	--	--
Mound system	--	--	--	--
Don't know	--	--	--	--
Other	6	10	--	--
SYSTEM PUMPING	No. of Response	Percent	No. of Response	Percent
More than once per year	4	7	2	13
Every year	8	14	2	12
Every 2 years	9	15	5	31
Every 3 years	20	34	4	25
Every 4 years	1	1	--	--
Every 5 years	1	1	1	6
Every 10 years	--	--	--	--
When problems	4	7	--	--
Never	6	10	1	6
No response	3	5	1	6
New system	3	5	--	--
PROBLEMS	No. of Responses	Percent	No. of Response	Percent
Freeze ups	--	--	--	--
Back ups	--	--	--	--
Inadequate drainage	2	3	2	12
Some - not bad	3	5	--	--
None in the last 2 years	3	5	2	12
None at all	31	53	6	38
No reply	20	34	6	38
LAWN SERVICE USE	No. of Response	Percent	No. of Response	Percent
Yes	6	10	--	--
No	50	85	16	100
No reply	3	5	--	--

Table 10. Comfort Lake septic system self-evaluation results. Survey was conducted during the late spring early summer of 1999.

1. What is the age and capacity of your septic system?

	A. Low risk System is five years old or less	**B. Medium risk** System is between six and twenty years old	**C. High risk** System is more than twenty years old
North side of lake	6	6	0
South side of lake	5	2	1
East side of lake	9	8	2
West side of lake	6	4	3
No location given	3	7	2
Total - all locations	27	27	8

2. What is the depth between your drainfield and the groundwater table or a limiting zone?

	A. Low risk Groundwater remains at least 4 feet below surface and limiting zone greater than 4 feet below surface	**B. Medium risk** Groundwater rises to between 2 and 4 feet of the surface and limiting zone between 2 and 4 feet from surface.	**C. High risk** System is subject to annual flooding or groundwater comes within 2 feet of surface. Limiting zone less than 2 feet from surface.
North side of lake	8	3	0
South side of lake	5	2	0
East side of lake	13	2	0
West side of lake	12	1	0
No location given	11	1	0
Total - all locations	49	9	0

3. Where is your septic system located in relationship to the lake?

	A. Low risk Drainfield is at least 200 feet from surface water.	**B. Medium risk** Drainfield is at least 100 feet from surface water.	**C. High risk** Drainfield is less than 100 feet from surface water.
North side of lake	7	5	0
South side of lake	5	3	0
East side of lake	5	8	5
West side of lake	7	3	3
No location given	7	5	0
Total - all locations	31	24	8

4. Are trees and shrubs planted near your septic system?

	A. Low risk Grass or other shallow-rooted plants over drainfield.	**B. Medium risk** Shallow rooted shrubs on or near the drainfield.	**C. High risk** Trees and shrubs are growing on or near the drainfield.
North side of lake	12	0	0
South side of lake	7	0	1
East side of lake	14	1	3
West side of lake	7	2	4
No location given	11	2	0
Total - all locations	51	5	8

5. Does runoff drain away from your septic system?

	A. Low risk All surface runoff is diverted away from the drainfield.	**B. Medium risk** Some surface water flows into the drainfield area.	**C. High risk** All or nearly all runoff flows onto drainfield.
North side of lake	11	1	0
South side of lake	7	1	0
East side of lake	14	4	0
West side of lake	11	2	0
No location given	12	0	0
Total - all locations	55	8	0

6. How much water do you use?

	A. Low risk Only water-conserving fixtures and practices are used. Drips and leaks are fixed immediately.	**B. Medium risk** Some water-conserving step are taken.	**C. High risk** Standard high-volume fixtures are used. No effort is made to conserve water.
North side of lake	6	5	1
South side of lake	5	3	0
East side of lake	12	7	0
West side of lake	6	5	2
No location given	7	5	0
Total - all locations	36	25	3

7. Do you use a garbage disposal or dispose of solid waste materials?

	A. Low risk There is no garbage grinder in the kitchen. No grease or coffee ground are put down the drain. Only toilet tissue is put in toilet.	**B. Medium risk** There is moderate use of garbage grinder, and some solids are disposed of down the drain.	**C. High risk** There is heavy use of a garbage grinder, and /or many solids are disposed of down the drain. Many paper products or plastics are flushed down the toilet.
North side of lake	9	3	0
South side of lake	8	0	0
East side of lake	17	2	0
West side of lake	8	5	0
No location given	12	0	0
Total - all locations	54	10	0

8. Do you pour grease and oil down your sink or use cleaning products?

	A. Low risk There is careful use of household chemicals. No grease or oil, solvents, fuels, paint, or other hazardous chemicals are poured down the drain.	**B. Medium risk** There is occasional disposal of grease and oil or hazardous chemicals in wastewater system.	**C. High risk** There is heavy use of strong cleaning products that end up in the wastewater. Hazardous chemicals or grease and oil are disposed of in the wastewater system.
North side of lake	11	1	0
South side of lake	8	0	0
East side of lake	19	0	0
West side of lake	12	1	0
No location given	12	0	0
Total - all locations	62	2	0

9. Have you protected your septic system from physical damage?

	A. Low risk Structures, vehicles and other heavy objects or activities are kept from the drainfield area.	**B. Medium risk** The drainfield is occasionally compacted by heavy objects or activities.	**C. High risk** Vehicles, livestock, heavy objects, structures are permitted in the drainfield area.
North side of lake	12	0	0
South side of lake	8	0	0
East side of lake	19	0	0
West side of lake	12	1	0
No location given	11	1	0
Total - all locations	62	2	0

10. Has your septic tank been inspected and cleaned recently?

Maps and Records	A. Low risk I keep a map and good records of repair and maintenance.	B. Medium risk The location of my tank and date of last pumping are known but not recorded.	C. High risk The location of my system is unknown. I do not keep a record of pumping and repairs.
North side of lake	8	2	1
South side of lake	6	2	0
East side of lake	12	6	0
West side of lake	8	5	0
No location given	7	5	0
Total - all locations	41	20	1
Tank pumping	**A. Low risk** The septic tank is pumped on a regular basis as determined by annual inspection or about every 1-2 years.	**B. Medium risk** The septic tank is pumped, but not regularly.	**C. High risk** The septic tank is not pumped.
North side of lake	7	4	0
South side of lake	6	2	0
East side of lake	12	5	0
West side of lake	12	1	0
No location given	8	3	1
Total - all locations	45	15	1
Conditions of tank and baffles	**A. Low risk** The tank and baffles are inspected and repaired promptly.	**B. Medium risk**	**C. High risk** The conditions of the tank and baffles is unknown.
North side of lake	8	2	1
South side of lake	4	2	2
East side of lake	12	1	2
West side of lake	12	0	1
No location given	8	1	2
Total - all locations	44	6	8

11. Is your system exhibiting any signs of problems?

	A. Low risk Household drains flow freely. There are no sewage odors inside or outside. Soil over drainfield is firm and dry.	B. Medium risk Household drains run slowly. Soil over drainfield is sometimes wet.	C. High risk Household drains back up. Sewage odors can be noticed in the house or yard. Soil is wet or spongy in the drainfield area.
North side of lake	12	0	0
South side of lake	8	0	0
East side of lake	18	0	0
West side of lake	13	0	0
No location given	10	2	0
Total - all locations	61	2	0

II.2C. Stream Assessment

An important source of nutrients such as phosphorus is delivered to Big and Little Comfort Lakes by stream flow. Both lakes are part of the Sunrise River system. Monitoring stations were set-up at four locations along these streams to characterize flows and phosphorus concentrations. A map of stream sample sites in the watershed is shown in Figure 11. Details of the hydrology, water chemistry, and nutrient loading follow in the next few pages.

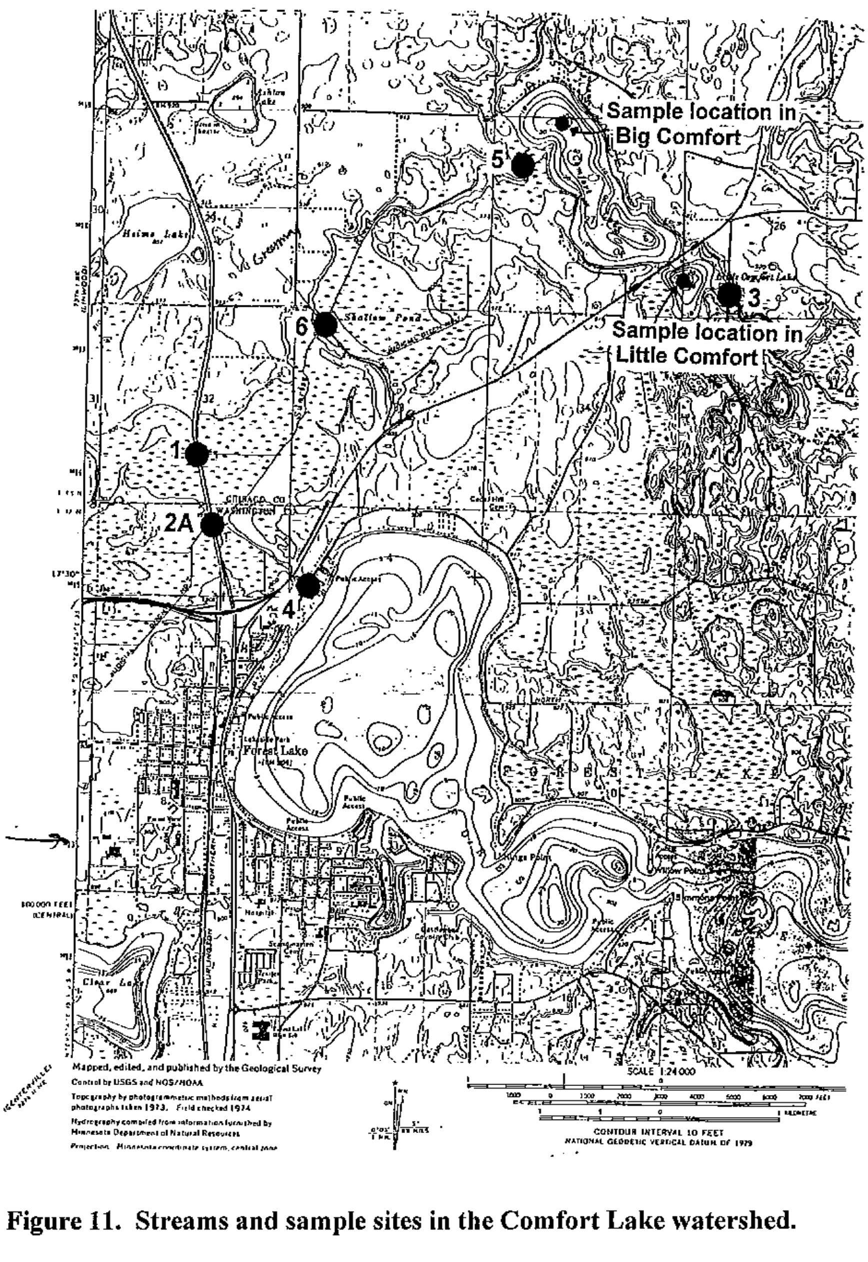


Figure 11. Streams and sample sites in the Comfort Lake watershed.

Watershed Hydrology

The amount of water flowing by four monitoring sites was recorded at 15 minutes intervals from February 27 through October 12, 1998 (sites 1, 2, 3, and 5).

The cumulative amount of water for each site is shown in Table 11. Since the volume of water is known and the area it drains is known, the amount of runoff (in inches) per watershed acre can be determined (Table 11).

The Forest Lake subwatershed had the highest amount of runoff per watershed acre. Subwatershed 3, which flows into Little Comfort Lake, had the lowest amount. Highest flows occurred in the spring.

Additional water quality data are found in the Addendum.

Table 11. Watershed runoff characteristics for period of flow recording (Feb 27-Oct 12, 1998, 228 days). Rainfall for the period was approximately 24 inches.

Sub-watershed	Average Daily Flow (cfs)	Acre-ft per Day	Ac-ft Over 228 day Period	Watershed Size (ac)	Inches of Runoff per Acre	% Runoff
Big Comfort						
1	0.51	1.01	230	1,357	2.04	8%
2	1.82	3.61	823	1,641	6.01	25%
5	--	--	543	1,861	3.50*	14%
4	--	--	6,293**	6,535	11.56**	48%
1, 2, 4, 5	17.43	34.6	7,889	11,394	8.31	35%
Little Comfort						
3	4.81	9.54	2,175	9,341	2.80	12%

*Estimated based on more impervious surface than subwatershed 1 but less than subwatershed 2.
**Estimated by substracting flows of subwatersheds 1,2, and 5 which equals 1,596 ac-feet for the 228 day period from total flow measured which was 7,889 ac-ft, leaving 6,293 acre-feet.

Stream Water Quality Data

Stream monitoring was conducted by MPCA in 1997 and by the Phase I project team (D.Schuler, Lake Association volunteers, and Steve McComas) in 1998. Total phosphorus results are shown in Table 12. Data from 1997 are base flows. Data from 1998 are both base flows and storm event flows. Storm event monitoring results in 1998 are indicated with an asterisk. Both flow data and total phosphorus data are found in Addendum C.

Storm event sampling results in 1998 show a range of total phosphorus concentrations. This is typical for storm flows. Phosphorus concentrations often vary over the course of the storm hydrograph.

Stream Water Quality Data - continued

Table 12. Stream total phosphorus sampling. Data are shown in parts per billion. Weeks correspond to week 1 = days 1-7; week 2 = days 8-14; week 3 = days 15-21: week 4 = days 22 to end.

month-week	Site 1		Site 2		Site 6	Site 5			Site 3	
	1997	1998	1997	1998	1998	1994	1997	1998	1997	1998
1-3								27		35
2-3		116		125	75			83		125
3-1										
3-2										
3-3										
3-4*								800/35/771		49/54
4-1*	110	89		83			71	73	112	83
4-2			60				30	37	70	31
4-3							--			
4-4	80	89	70				40	50	48/30	25/47
5-1				92	75	40	30	100		59
5-2	100	224	130			59		56	40	
5-3*	180	297/364	50	86/92		46	40	108/123	50	89/120
5-4*		967/204		246/115		88		98/106/122		188/87
6-1	150		220			252	60		90	
6-2						67				70
6-3	80	378/200	70	65/56	392	114	10	97	90	496
6-4*		297/136/157/133		171/153/69/324	85	94		116/186/178		321/222/133/103
7-1	140	164	150	276		113	20		120	117
7-2						75				
7-3*	320	211/274/122	90	203/189/222	126	--	130	159	80	167/200/247
7-4						--				
8-1*	120	822/80	30	247/264	155	--	120	112/118/104	110	239/143/143
8-2*				239		--		138		352
8-3*	160	80/705/308/115	80	250/890/165	226/216	--	60	140/331/66/149/66	80	179/360/627/176
8-4		154		157	154	--		90		129
9-1						--		64		94
9-2						81				
9-3								69		
9-4										72
10-1										85
11-1								69		180
11-4							25		34	
12-2							31		37	

* indicates storm event sample in 1998.

A snapshot of spring water quality conditions in the Little Comfort watershed for the School Lake watershed in 1997 is shown in Table 13.

Table 13. Water quality parameters for grab samples, collected 4.22.97 (at base flow).

Site	TSS (mg/l)	Tot. Dis. Solids (mg/l)	NO_2/NO_3 (μg/l)	NH_3/NH_4-N (μg/l)	TKN (μg/l)	TOP (μg/l)	TP (μg/l)	CBOD, 5-day (mg/l)
Little Comfort Inlet	4.8	350	<50	<20	780	43	48	
South Inlet, School Lake	4	150	690	<20	1,470	7	355	1.4
Northeast Inlet, School Lake	<1.0	140	<50	<20	710	30	48	
Ecoregion Reference Streams								
1970-1982 Annual means	13.7		160	200			130	2.7
1970-1992 Annual medians	8.8		100	200			90	2.2

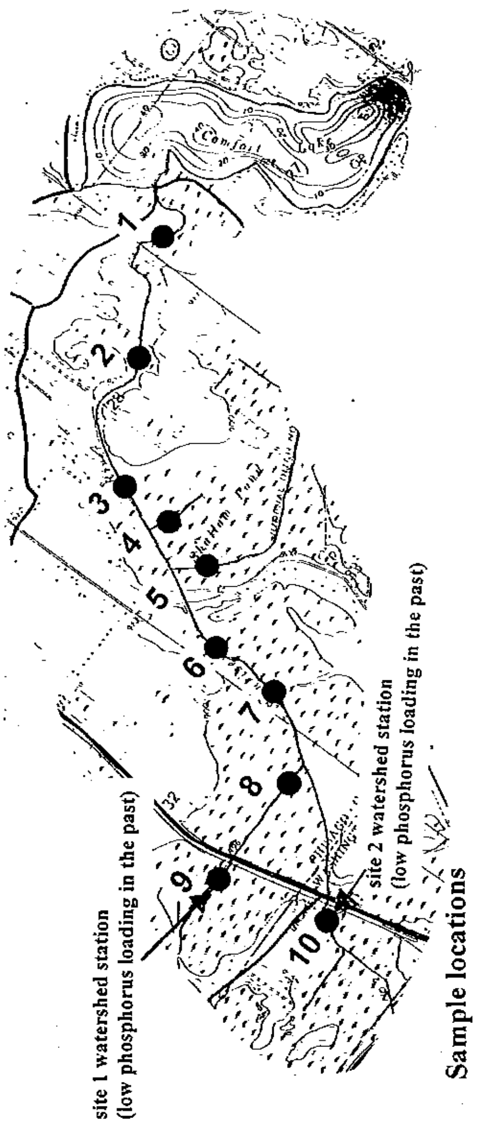
Phosphorus and Total Suspended Solid Concentrations
Phosphorus and suspended solid stream concentrations were calculated based on monitoring with automatic equipment at four stream sites. Concentrations from Forest Lake and Bone Lake were based on monitoring conducted through the Met Council CAMP program. Average concentrations are shown in Table 14. Additional water quality data are listed in the Appendix, pp 25-29.

Table 14. Flow weighted mean concentrations for phosphorus and total suspended solids.

	Total Phosphorus (ppb)	Total Suspended Solids (ppm)
Big Comfort		
1	169	21
2	170	12
4	30	--
5	263	25
Little Comfort		
Bone Lake	34	--
3	123	21

Sunrise River Phosphorus and Iron Survey, 1999

- Sunrise River has high iron levels.
- Negative redox is found at stations 5 and 8 although oxygen was present. Measurements in the ditch show the bottom water has lower oxygen concentrations than the surface water. There may be a strong sediment oxygen demand.
- Station 4 lateral has higher redox and lower phosphorus concentrations compared to the station 5 lateral. Fe/TP ratios are similar.
- Maybe station 5 lateral intercepts low redox water, and station 4 has fresher water.
- Next round of sampling should employ in-line filtering to get the Dissolved Fe/Total Fe breakdown.
- Maybe we can't easily lower overall phosphorus loading from Sunrise River, but we could change the form of phosphorus from ortho-phosphorus to total phosphorus. This could reduce algae growth in Comfort Lake.
- One way to reduce ortho-phosphorus concentrations may be to convert dissolved iron to solid iron which would then scavenge phosphorus from the water column.
- Its possible that by aerating a stretch of river with an in-stream airline, iron reprecipitation could combine with phosphates and make them unavailable for algae growth.



Sunrise Creek sampling results, July 12, 1999. Data collected by Mark Tomasek, Shannon Lotthammer, Celine Lyman, and Steve McComas. Station locations are shown below.

Station	Time	Depth (m)	Temp (°C)	DO (mg/l)	DO (%sat)	OPR (mV)	pH (SU)	Cond (μs/cm)	Phos (μg/l)	Iron (μg/l)	Fe/TP ratio	Flow vel (ft/sec)	Setting
Check	10:14	0.3	20.6	4.8	55	136	7.4	446	--	--	--	--	Sunrise River in woods
Check	10:15	0.5	20.6	4.8	55	136	7.4	446	--	--	--	--	
1.	10:44	T 0.3	21.9	5.3	63	141	7.4	442	81	1,280	15.8	--	Sunrise River, in woods
	10:46	B 0.3	22.0	5.1	60	142	7.4	440	87	1,170	13.5	--	
2.	11:08	0.2	23.2	5.4	66	152	7.4	435	--	--	--	--	Sunrise River, in woods
	11:10	0.4	23.2	5.2	62	134	7.4	434	--	--	--	--	
3.	11:30	T 0.1	23.0	5.1	--	--	--	--	81	1,160	14.3	0.45	Sunrise River, in wetlands, North of Greenway
	11:35	B 1.0	23.0	5.1	--	--	--	--	78	1,160	14.9	0.61	
4.	11:45	0.5	24.0	3.7	46	57	6.5	333	61	1,350	22.1	--	Lateral to Sunrise River
5.	13:17	T 0.4	23.9	5.3		- 21	6.9	560	310	6,890	22.2	--	Lateral to Sunrise River (JD#1)
	13:18	B 0.4	24.1	0.9	11	- 30	6.8	558	-	-	--	--	
6.	12:22	0.6	24.4	6.7	82	135	7.3	449	-	--	--	0.31	Sunrise River, in wetlands, South of Greenway
	12:24	0.8	24.5	6.5	80	44	7.4	439	--	--	--	0.22	
7.	12:33	T 0.4	24.5	7.0	86	112	7.5	431	109	1,990	18.3	0.53	Sunrise River, in wetlands, South of Greenway
	12:36	B 0.5	24.6	6.9	85	98	7.5	441	112	1,490	13.3	0.43	
8.	13:00	0.4	23.6	3.8	45	- 37	7.1	393	694	9,630	13.9	--	Lateral to Sunrise River (Heims Lake)
	13:14	0.4	23.8	1.0	12	- 60	6.8	569	--	--	--	--	
9.	13:46	0.4	22.0	3.5	42	21	7.2	430	276	6,330	22.9	--	Lateral at Hwy 61 (Heims Lake)
10.	13:55	0.5	23.1	1.9	23	87	7.0	663	212	3,950	18.6	--	Sunrise River at Hwy 61
	13:57	1.3	23.1	1.8	22	73	7.0	663	--	--	--	--	
11	12:28	--	--	--	--	--	--	--	165	3,440	20.9	--	Carp turbidity in ditch, between 6 & 7

Watershed Nutrient Loading

Combining flow and nutrient concentrations pounds of phosphorus passing by a monitoring site were estimated (Table 15).

Next the drainage area at a sampling site was established. When the pounds of phosphorus are divided by the number of acres in a subwatershed, you end up with pounds of phosphorus delivered per watershed acre. The methods used to determine this loading are summarized in Table 16. A diagram showing pounds of phosphorus/acre for various subwatersheds is shown in Figure 12.

Table 15. Site loading calculations based on monitored flows and sampling from April - September, 1998.

Site	Big Comfort			Little Comfort	Outlet
	1	2	1, 2, 4, 5	3	7
Flow (ha-m)*	0.16	0.61	5.66	1.61	4.36
TP Conc (ppb) (FWM)**	169	170	263	123	34
TP Load (kg)	27	103	1,486	197	150
TP Load (pounds)	60	227	3,269	434	330
OP Conc (ppb) (FWM)**	83	147	59	77	16
OP Load (kg)	14	89	335	124	70
TSS Conc (ppm) (FWM)**	21	12	25	21	4
TSS Load (kg)	3,403	6,993	140,945	33,080	19,331

*hectometer = 1,000,000 cubic meters
**FWM = flow weighted mean

Table 16. Methods used to determine phosphorus export from the subwatersheds. Monitoring period was April-September, 1998.

Sub-watershed	Export		Sub-watershed Size (ac)	Methods Used to Calculate Loading
	(lbs-P/ac/yr)	Pounds of Phos		
1	0.05	60	1,357	Automatic flow monitoring and automatic sample collection station. Flow weighted mean (FWM) was 169 ppb and flow was 0.16 ha-m.
2	0.14	227	1,641	Automatic flow monitoring and automatic sample collection station. FWM = 170 ppb; flow = 0.61 ha-m.
4	0.08	513	6,535	Outlet from Forest Lake: used an average phosphorus concentration of 30 ppb and an average runoff of 11.56 inches per year. Based on a 6,535 acre watershed.
5	1.3	2,469	1,861	Automatic flow monitoring and automatic sample collection station. Total pounds of phosphorus at this station reflected inputs from 1, 2A, and 4. To isolate loading from Subwatershed 5, loads from Subwatershed 1, 2, 4 were calculated and subtracted from the total load monitored at Station 5.
3	0.08	328	4,164	Automatic flow monitoring and automatic sample collection station. FWM = 123; Flow = 1.61 ha-m.
Bone Lake	0.02	106	5,177	Outlet from Bone Lake. 12% runoff = 2.52 inches = 0.21 feet and outlet concentration of 34 ppb.
Direct Drainage Big Comfort	0.50	302	603	Export coefficient based on Wisconsin spreadsheet model.
Direct Drainage Little Comfort	0.50	100	200	Export coefficient based on Wisconsin spreadsheet model.

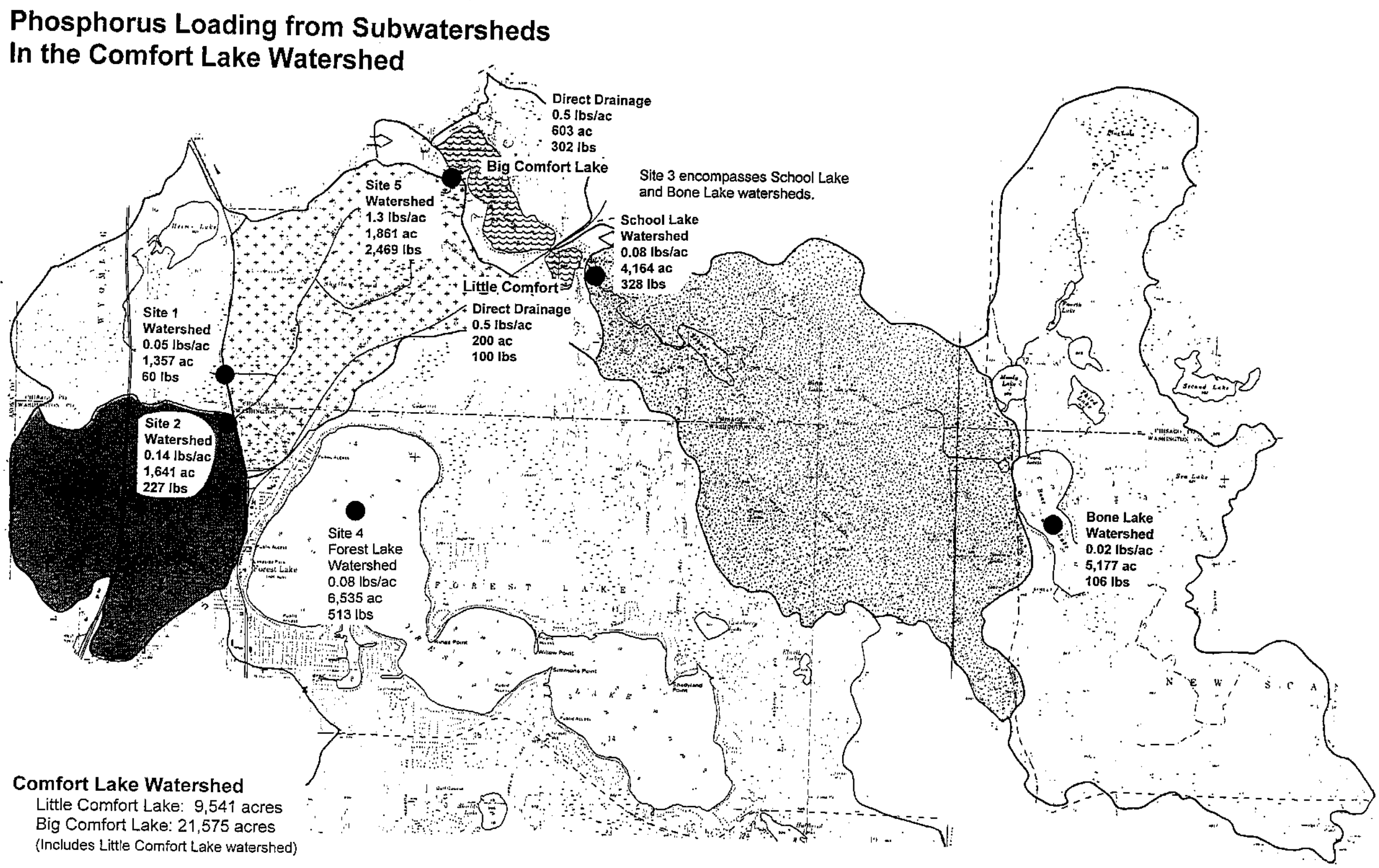


Figure 12. Diagram showing pounds of phosphorus/acre for various subwatersheds in the Comfort Lake watershed.

II.2D. Comfort Lake Assessment

Big and Little Comfort Lakes were monitored as part of this study from November 1997 through November 1998. That information along with other lake data collected over the years is presented in this section. Monitoring details are given in Addendum C.

A summary of lake characteristics is shown in Table 17.

Table 17. Morphometric, watershed and fishery characteristics for Big Comfort and Little Comfort Lakes.

	Big Comfort	Little Comfort
STORET I.D. #	13-0053	13-0054
Area[1]	219 acres (88.7 ha)	37.3 acres (15.1 ha)
Mean depth	19.1 feet (5.8 m)	17.8 feet (5.4 m)
Maximum depth	45 feet (13.7 m)	54 feet (16.5 m)
Volume	4,179.3 acre-feet (5.2 hm^3)	664.7 acre-feet (0.82 hm^3)
Littoral area	41%	44%
Fetch	0.9 mile (1.5 km)	0.3 mile (0.51 km)
Watershed area [2]	21,575 acres (8,731 ha)	9,541 acres (3,861 ha)
Watershed area:lake	88:1	256:1
Estimated Average Water Residence Time:	0.58 years	0.18 years
Fisheries: Ecological Classification Management Classification	 Centrarchid Centrarchid	 Centrarchid Centrarchid
Public Access	1	0
Inlets	2	1
Outlets	1	1

[1] Planimetered by MPCA from MnDNR contour map.
[2] Areas described by Chisago/Washington SWCD in 1994 were different then what was delineated in this study. SWCD areas were 13,596 acres for Big Comfort Lake and 2,166 acres for Little Comfort Lake (excluding lake areas).

Lake Levels

Official DNR records start in 1952 then there is a 14-year gap and levels pick up in 1966. It appears the annual average lake level has gone up about a foot since the 1970s (Figure 13). The minimum level has been about 885 feet in 1969 and the maximum was about 888 in 1975. A swing of about 3-feet over 30 years of record is not uncommon for glacial lakes.

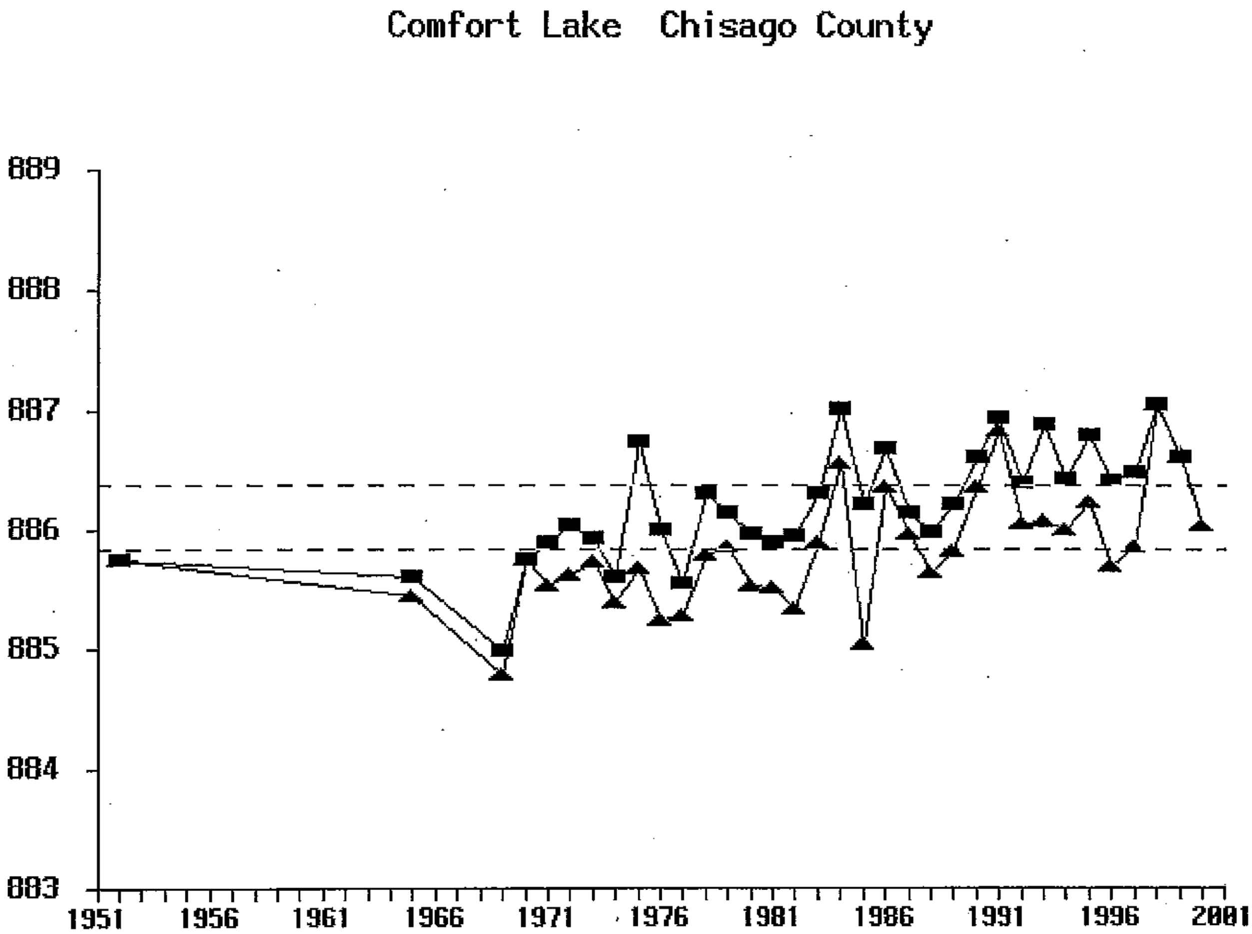


Figure 13. Comfort Lake levels since 1952.

Dissolved Oxygen and Temperature Profiles

Both Big and Little Comfort Lakes strongly stratify through the summer. This means warm water sits on top of cold water and the warm top water does not mix with the cold bottom water. Representative temperature profiles are shown below in Figure 14 (data tables are in the appendix).

Often, when lakes are strongly stratified by temperature and don't mix, the bottom water loses oxygen. This is the case for both Big and Little Comfort Lakes.

Two of the ramifications of a loss of oxygen are that fish will be forced to remain in the upper warm water of the lake and that phosphorus is generally released from bottom lake sediments when oxygen is depleted.

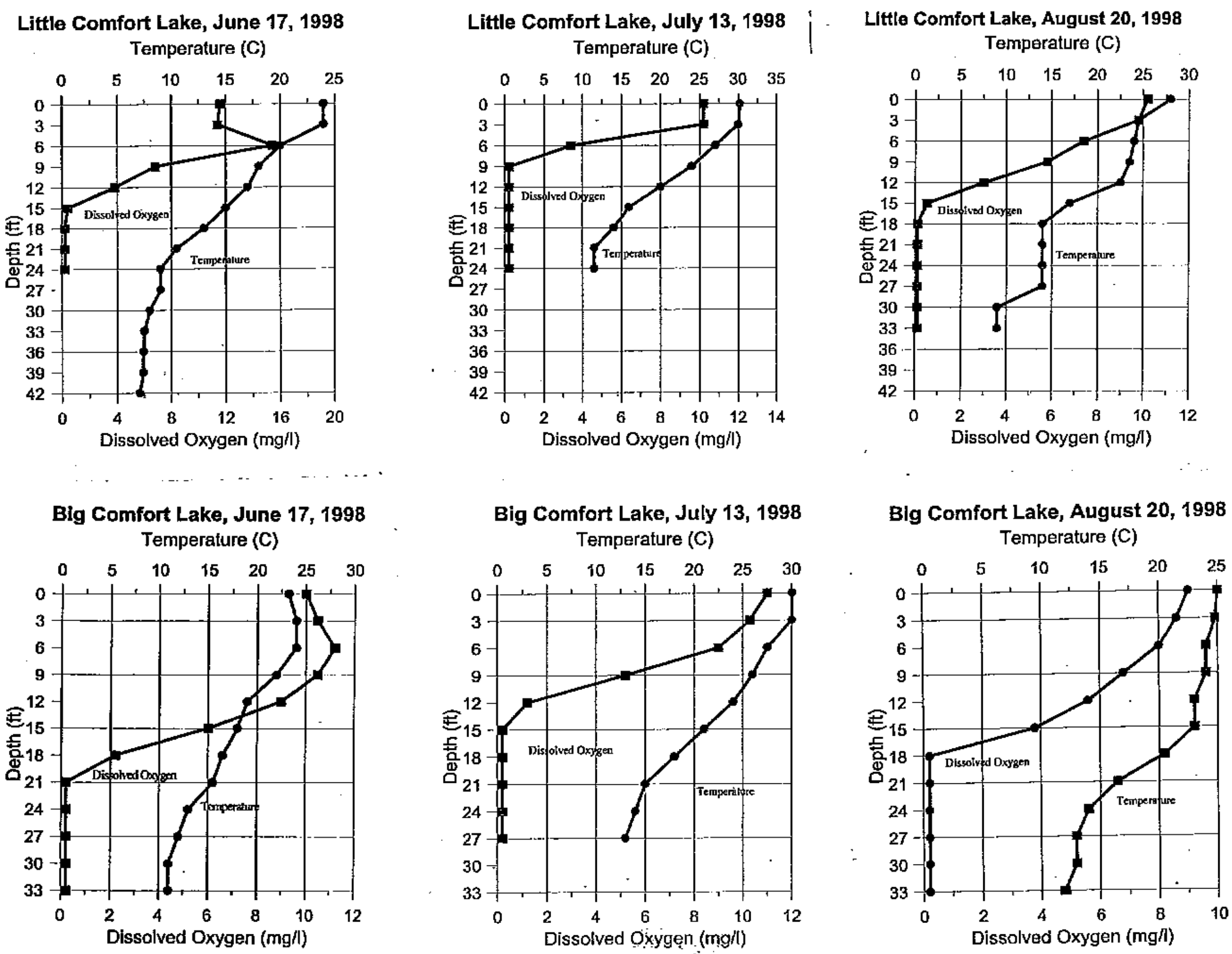


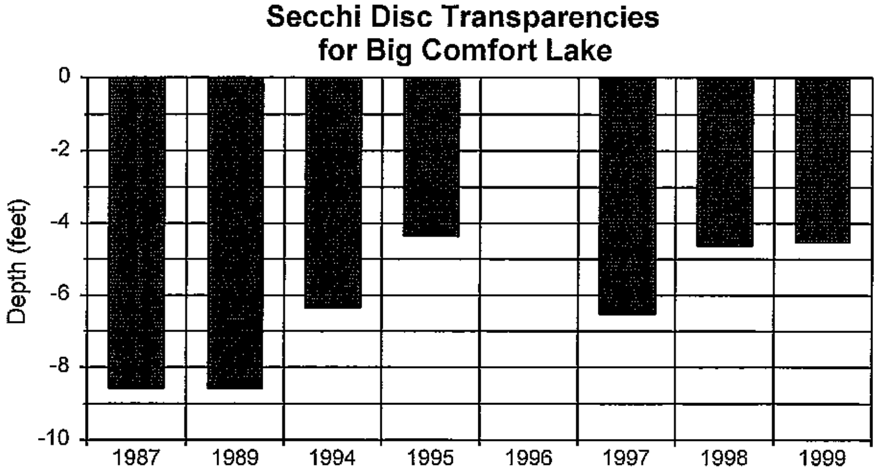
Figure 14. Dissolved oxygen/temperature profiles for 1998.

Water Clarity Based on the Secchi Disc Transparency

Water transparency in Big Comfort Lake has been an area of discussion in recent years. Lake users noticed an increase in algae starting in about 1994. Unfortunately, secchi disc records are scarce prior to 1994. A summary of monthly secchi disc data is shown in Table 17a and seasonal readings are graphed in Figure 15.

Table 17a. Monthly secchi disc records for Big and Little Comfort Lakes.

				CLMP	MPCA				CLMP	BWS	CLMP
	1987	1989	1989	1994	1994	1995	1996	1997	1998	1998	1999
Big Comfort											
May				7.2	5.8					6.5	
June				6.9	5.5					4.6	
July				7.3	6.7					2.7	
August				5.2	4.6					3.5	
September				--	6.4					4.4	
Growing Season Average	***8.5***	***7.8***	***9.2***	***6.7***	***5.8***	***4.3***	**--**	***6.5***	***4.8***	***4.3***	***4.5***
(n)				(11)	(10)					(18)	(15)
Little Comfort											
May				6.9	--					6.3	
June				6.8	6.6					4.0	
July				6.3	4.6					2.3	
August				4.6	5.9					2.7	
September				--	4.6					4.0	
Growing Season Average				***6.2***	***5.4***					***3.9***	
(n)				(6)	(4)					(10)	



Water Clarity - continued: From the middle of May in 1998 through November 1998, the secchi disc transparency was similar in Big and Little Comfort Lakes.

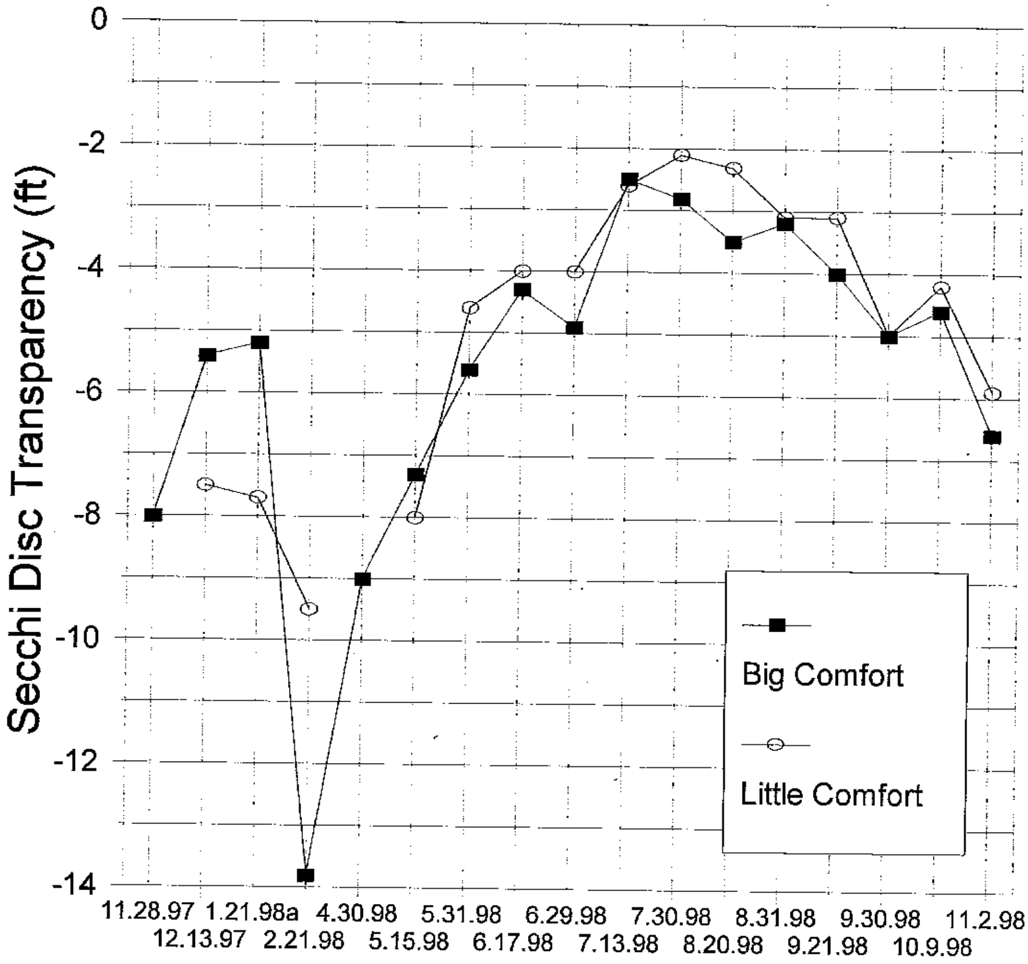


Figure 15. Water transparency in Big Comfort and Little Comfort Lake for November 1997 through November 1998.

Water Chemistry

A summary of water chemistry results for 1994 and 1998 for the Comfort Lakes is shown in Table 18. Phosphorus levels are slightly higher and secchi disc transparency is slightly lower in 1998 compared to 1994. Nitrogen is the same. Big Comfort and Little Comfort Lake do not fit within the typical range for secchi disc transparency for lakes in the North Central Hardwood Forest Ecoregion. For total phosphorus, Big Comfort fits within the range and Little Comfort Lake does not (Table 18).

Table 18. Summary of Big Comfort and Little Comfort Lakes data for 1994 and 1998.

Parameter	Big Comfort		Little Comfort		Typical Range for NCHF Ecoregion
	1994	1998	1994	1998	
Total Phosphorus (ppb)	35	40	51	58	23-50
Chlorophyll a (ppb)					
Mean	16	11	32	15	5-22
Maximum	30.4	24	56.7	37	7-37
Secchi disc (feet)	6.5	4.3	5.8	3.9	4.9-10.5
Total Kjeldahl Nitrogen (mg/l)	1.1	1.1	1.3	1.2	0.62-1.2
Nitrite + Nitrate - N (mg/l)	0.05	<0.01	0.05	<0.01	<0.01
Alkalinity (mg/l)	155	172	140	164	75-150
Color (Pt-Co Units)	35	--	45	--	10-20
pH (SU)	8.2	8.1	8.3	7.9	8.6-8.8
Chloride (mg/l)	19	--	9.3	--	4-10
Total Suspended Solids (mg/l)	4.3	--	4.4	--	2-6
Total Suspended Inorganic Solids	1	--	0.8	--	1-2
Turbidity	2.3	--	2.8	--	1-2
Conductivity (umhos/cm)	313.3		263.8		300-400
TN:TP Ratio	33:1		27.1		25:1-35:1

* North Central Hardwood Forest Ecoregion

Water Chemistry - continued: The seasonal variation in surface phosphorus concentrations for Big and Little Comfort Lakes is shown in Figure 16. A growing season (May-Sept) average of 30 ppb is a reasonable average for North Central Hardwood Forest Ecoregion lakes. Both Big and Little Comfort Lakes were above this benchmark (Table 19). Little Comfort Lake had higher phosphorus levels than Big Comfort through July and August. Phosphorus levels were similar in April and May. In Big Comfort Lake, a high phosphorus results was recorded on July 13, 1998. The cause could be curlyleaf pondweed dieback, bottle contamination or some other factor.

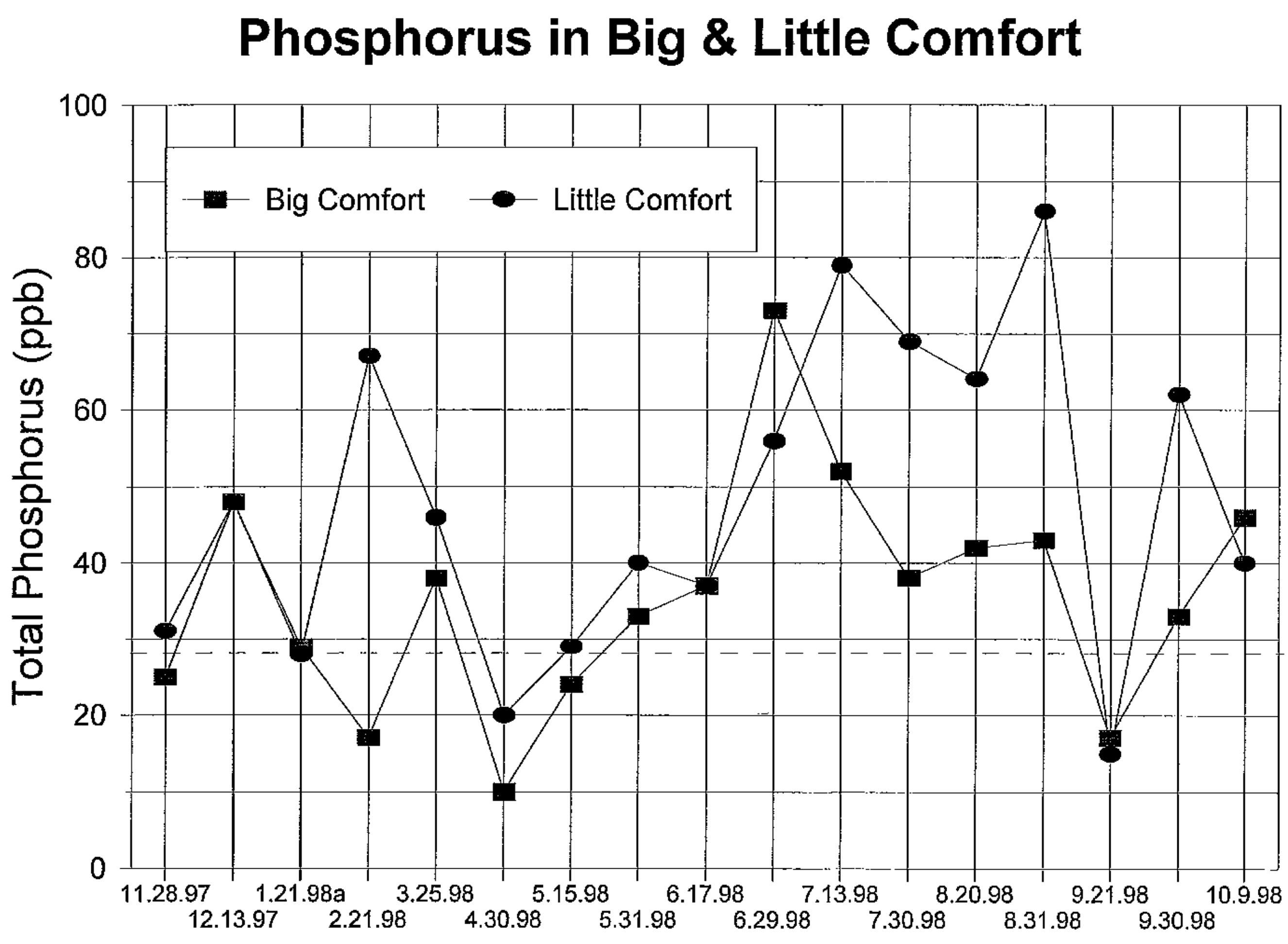


Figure 16. Total phosphorus concentrations for Big and Little Comfort Lakes over a one year period (Nov 1997 - Oct 1998).

Water Chemistry - continued: Water samples were collected at the top and bottom of Big and Little Comfort Lakes in 1998. Several bottom samples were also collected by MPCA in 1994. By June, there are higher phosphorus levels in the bottom water than the top water. The May-September average is shown in Table 19.

Because both lakes are strongly stratified, the high phosphorus concentrations in the bottom water should not substantially get mixed up into the surface water and contribute to algae blooms.

Phosphorus increases in the epilimnion are probably a function of epilimnetic deepening which in turn entrains enriched hypolimnetic water. This is coupled with the influence from watershed inputs in midsummer that are similar in temperature to epilimnetic water than to hypolimnetic water, so the inflows mix with the surface water and do not plunge into the hypolimnion. Curlyleaf dieback probably has a minimal impact.

Table 19. Total Phosphorus for top and bottom water for Big and Little Comfort Lakes in 1994 and 1998. Raw data are in the Appendix.

	Little Comfort Lake				Big Comfort Lake			
	1994	1998	1994	1998	1994	1998	1994	1998
	Top	Top	Bottom	Bottom	Top	Top	Bottom	Bottom
January	--	28	--	--	--	29	--	--
February	--	67	--	34	--	17	--	34
March	--	46	--	--	--	38	--	--
April	--	20	--	--	--	10	--	34
May	--	35	--	--	73	29	--	43
June	63	65	285	195	38	55	138	87
July	59	74	--	133	26	42	--	82
August	35	75	196	435	27	50	--	326
September	46	39	348	551	50	24	350	296
October	--	40	--	43	--	37	--	47
November	--	46	--	66	--	38	--	32
May-Sept	*51*	*58*	*276*	*329*	*43*	*40*	*244*	*167*

Water Chemistry - concluded: Other water chemistry parameters were collected over the sampling year and are summarized in Table 20. Orthophosphorus concentrations were higher in the bottom of Big Comfort Lake compared to the surface water. OP concentrations were slightly higher in the bottom water compared to the surface water in Little Comfort.

Nitrogen levels for both lakes show typical values (see Table 18 for Ecoregion values). Alkalinity and pH are within typical ranges for lakes in this area.

Table 20. Other water chemistry results collected periodically during the water year of 1997-1998. Data was collected by Blue Water Science and analyzed by EcoAgri Labs, Willmar.

	pH	Ortho-phosphorus (ppb)	Ammonia (mg/l)	TKN (mg/l)	Nitrate + Nitrite Nitrogen (mg/l)	BOD 5 (mg/l)	Total Alkalinity (mg/l)
Big Comfort Lake							
6.17.98		14					
6.29.98	8.0	12 - top 14 - bot	0.08	<0.5			195
7.30.98	8.1 - top -N 7.3-bot-N 8.2 - top - S 7.3-bot-S	5 - top - N 5 - top - S	0.105	1.38		4.6 - top - N 2.8-bot-N 3.8 - top - S 2.9-bot-S	
8.31.98	8.2	<10 - top N 170-bot <10 - top S 213-bot	0.030	0.77	<0.01	5.4	147
9.30.98		5 - top - N 80-bot-N <5 - top - S 221-bot-S				3.9 - top 9.1 - bot	
10.9.98			0.753	1.2	0.018		
11.2.98		49 - top 8 - bot					
Little Comfort Lake							
6.17.98		20					
6.29.98	7.9	22 - top 27 - bottom					199
7.30.98	8.0 - top 7.2 - bot	8	0.095	1.26		4.4 - top 0.5 - bot	
8.31.98	7.7	<10 - top <10-bot	0.052	1.17	<0.01	5.4	136
9.30.98		8 - top 77 - bot				4.2	
10.9.98			0.625	1.3	0.036		
11.2.98		19 -top 16 - bot					

Algae and Zooplankton

A qualitative examination of algae in Comfort Lake found that blue-green algae were the dominant algae in mid to late summer (Figure 17). A typical sequence of algal succession was found in both lakes, where diatoms were dominant in spring followed by green algae in early summer, and *Aphanizomenon,* a blue-green algae, in late summer.

Zooplankton are an important part of the food web in Comfort Lake. Zooplankton feed upon algae and are fed upon by planktivorous fish. Daphnids are better grazers on algae than copepods, ideally it would be best to have higher populations of daphnids, but the current populations are normal (Table 21). Zooplankton biomass was typical for lakes of moderate fertility. Daphnid biomass was generally greater than copepod biomass.

Table 21. Comfort Lake zooplankton counts for 1998, results are shown as number per liter.

	Big Comfort							Little Comfort							
	5.31	6.29	7.13	7.30	8.31	9.30	10.9	5.31	6.29	7.13	7.30	8.31	9.21	9.30	10.9
Daphnids	37	42	40	58	22	59	128	36	31	45	78	56	80	51	154
Big	17	2	9	10	1	5	41	21	11	19	26	2	3	24	55
Little	18	7	5	5	10	6	31	14	18	23	14	34	50	19	49
Bosmina	1	30	26	42	10	43	56	0	2	3	35	20	27	8	50
Chydorus	1	3	0	1	1	6	0	1	0	0	3	0	0	0	0
Copepods	71	39	68	32	32	72	60	68	55	84	34	74	60	49	106
Calonoids	16	3	4	7	2	26	26	35	11	1	2	13	27	6	36
Cyclopoids	12	31	33	25	19	43	31	21	43	43	32	48	49	40	65
Nauplii	43	5	31	0	11	3	3	12	1	40	0	13	14	3	5
Rotifers	3	2	0	0	4	2	3	2	0	0	0	5	3	2	0
Total	111	83	108	90	58	133	191	106	86	129	112	135	143	102	260

Table 22. Comfort Lake zooplankton biomass for 1998 are shown in μg/l-dry weight. Dry weights are from Long Lake, Detroit Lakes area and were determined by the MnDNR.

	Dry weights (μg/org)	Big Comfort							Little Comfort							
		5.31	6.29	7.13	7.30	8.31	9.30	10.9	5.31	6.29	7.13	7.30	8.31	9.21	9.30	10.9
Daphnids																
Big	12.00	204	24	108	120	12	60	492	252	132	228	312	24	36	288	990
Little	4.13	74	29	21	21	41	25	128	58	74	95	58	140	207	79	202
Bosmina	1.18	1	35	31	50	12	50	67	0	2	4	41	24	32	9	59
Chydorus	1.61	2	5	0	2	2	10	0	2	0	0	5	0	0	0	0
Copepods																
Calonoids	5.00	80	15	20	35	10	130	130	175	55	5	10	65	135	30	180
Cyclopoids	1.00	12	31	33	25	19	43	31	21	43	43	32	48	49	40	65
Nauplii	0.27	12	1	84	0	3	1	1	3	0.3	11	0	4	4	1	1

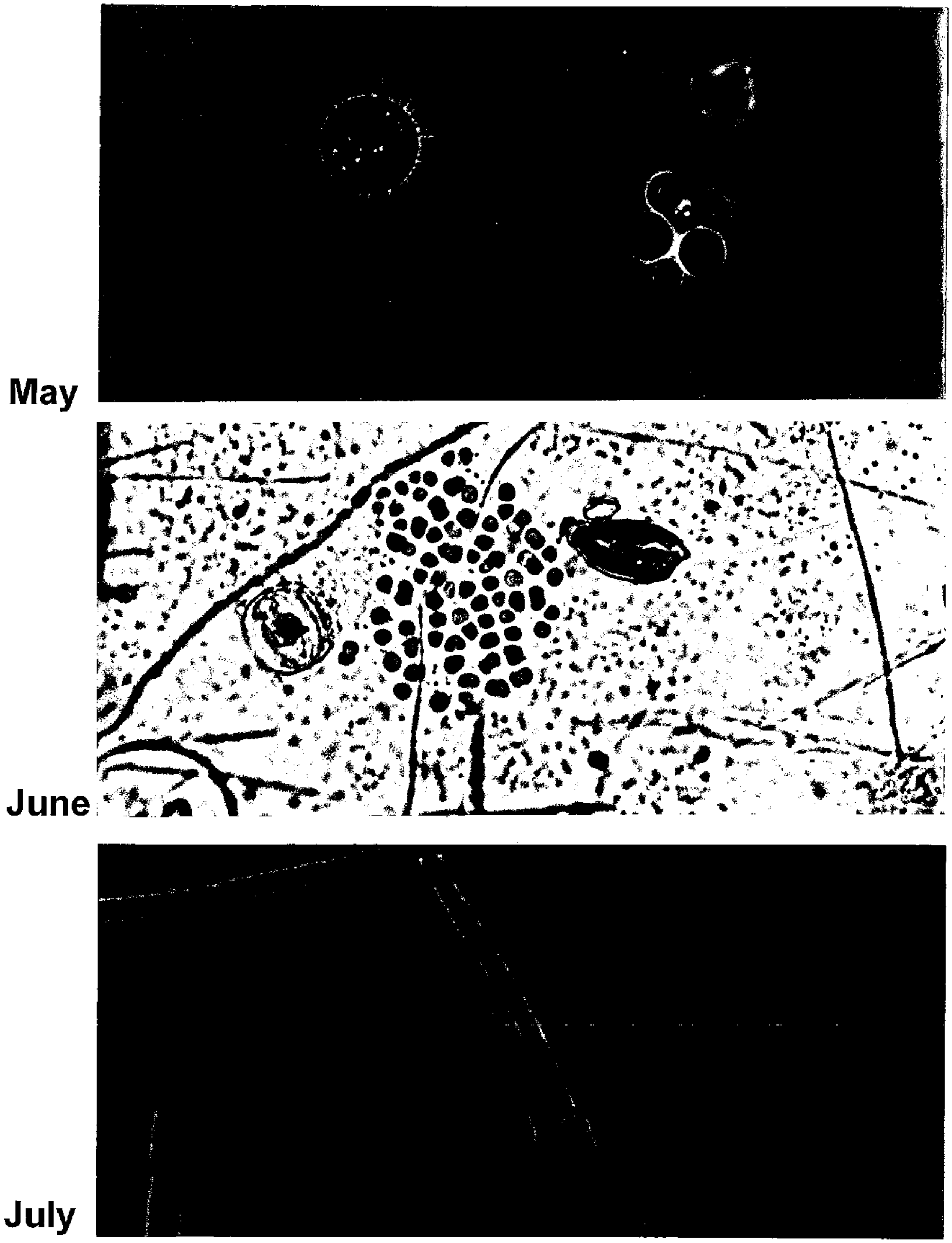


Figure 17. Representative algae found in Comfort Lake

Figure 18. An example of a copepod and a bosmina from Big Comfort Lake.

Aquatic Plants

An aquatic plant survey was conducted on Big Comfort Lake on September 28, 1997. Nine transects were conducted on Big Comfort Lake. Submerged aquatic plants were represented by four species (northern watermilfoil, coontail, sago pondweed, and stringy pondweed). One species of floating plants and emergent were found - spatterdock and bulrush respectfully. Aquatic plant coverage is shown in Figure 19. Sonar printouts are shown in the Appendix.

Another aquatic plant survey was conducted on Big Comfort Lake on August 31, 1998. Twenty transects were conducted around Big Comfort Lake. The aquatic plant community was similar to the 1997 survey and plants were scarce (Table 23). The only submerged plants were northern watermilfoil, coontail, sago pondweed, elodea, cabbage, and floatingleaf pondweed. Floating plants were represented by white water lilies and spatterdock. Bulrushes and cattails were found scattered around the perimeter of the lake. Submerged aquatic plant coverage on August 31, 1998 is shown in Figure 20 and floatingleaf plant coverage is shown in Figure 21.

An aquatic plant survey was conducted on Little Comfort Lake on September 21, 1998. Seven transects were conducted. Only one submerged aquatic plant was found, coontail. However two floating species were found, spatterdock and water lilies. Aquatic plant distribution is shown in Figures 20 and 21.

Aquatic plant coverage in Big Comfort Lake in 1997 and 1998 was about 20%. Coverage in Little Comfort Lake was about 15% in 1998. The Comfort Lakes are below the theoretical 40% bottom coverage that has been found (in Florida by Dr. Dan Canfield) to sustain clear water.

Big Comfort Lake is known to have curlyleaf pondweed. A spring plant survey is needed to characterize curlyleaf conditions.

Table 23. Comfort Lake aquatic plant survey results for 9.28.97. Water depths are shown under the transect. Density of aquatic plants on a scale from 1 to 5 (5 is the highest) is shown for a species found on a transect.

	T1		T2		T3		T4				T5	T6			T7	T8		T9
	3'	6'	4'	5'	3-5'	5'	0-2'	3'	4'	5'	6'	0-2'	2-5'	4'	4'	3'	4'	0-4'
Bulrush												1						
Spatterdock	4				2			3	3		4	1		1	3	1	1	4
Northern watermilfoil	2							2	2	2				1	1	2		
Coontail	1					1												1
Sago pondweed			4															
Stringy pondweed											1							

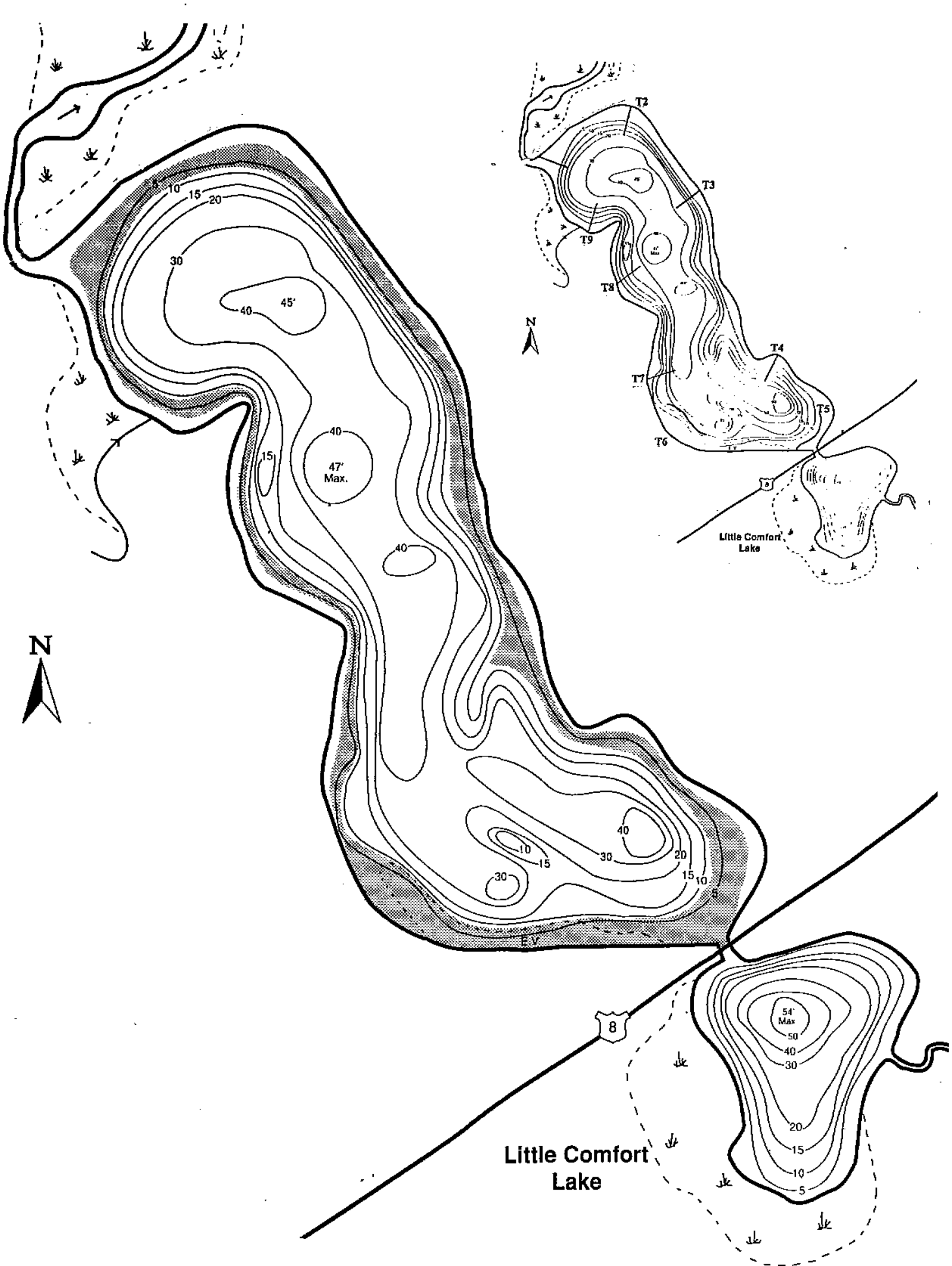


Figure 19. Aquatic plant coverage for Comfort Lake on September 28, 1997.

Table 24. Big Comfort Lake aquatic plant survey results for 8.31.98.

Plant Species	T1		T2			T3			T4	T5		T6		T7	T 8a	T 8	T 9	T 10	T 11	T 12	T 13	T 14	T 15	T 16	T 17	T 18	T 19	T 20
	2	5	0-3	5	6	0-5	6	8	0-5	0-5	6-7	0-5	6-8	0-5	0-3	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5	0-5
Bulrush																												
Cattails			P																									
White waterlily		1	1			1			1	1				1	1			3	2			1	1		1		4	1
Spatterdock			3			2			2	3				3		3	2	1	2	3	3	3	3	1	2	2	1	3
Northern watermilfoil		1																1				1						
Coontail														1			1								2		1	
Sago pondweed	2		1	1																								
Elodea	1	1																										
Cabbage															1													
Floatingleaf																									2	1		

Little Comfort Lake aquatic plant survey results for 9.21.98.

Plant Species	T1		T2		T3		T4		T5		T6		T7	
	3-5	7	3	7	3	6	3	6	0-3	4-5	0-3	6	3	6
Saptterdock	1								4					
Water lily	1		1		2	1	1		1					
Coontail	1				4		3	1	1		1			

Bulrush - present
Cattails - present

Depth of plant growth: 6 feet

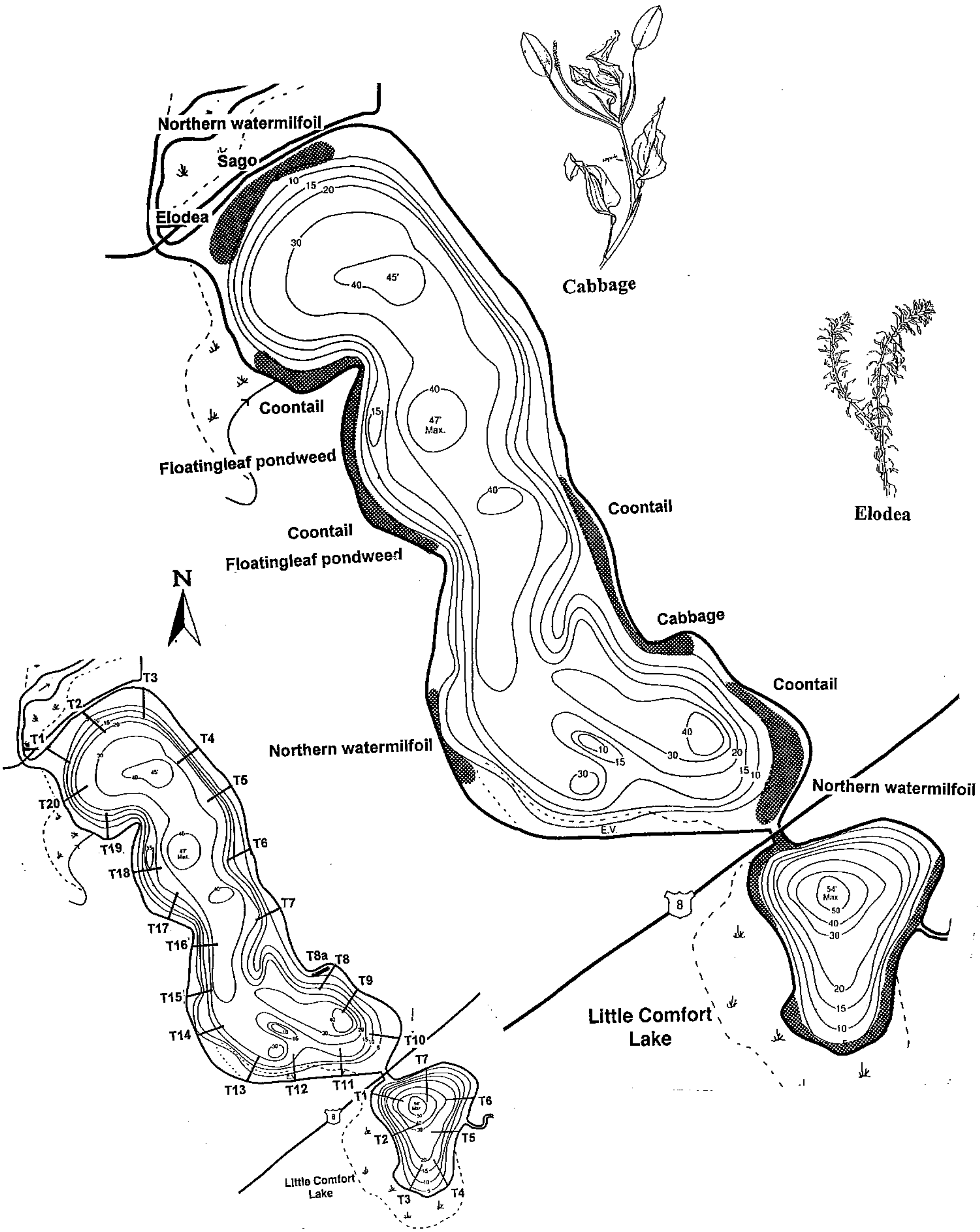


Figure 20. Submerged aquatic plant coverage on Big Comfort Lake, 8.31.98 and Little Comfort Lake, 9.21.98.

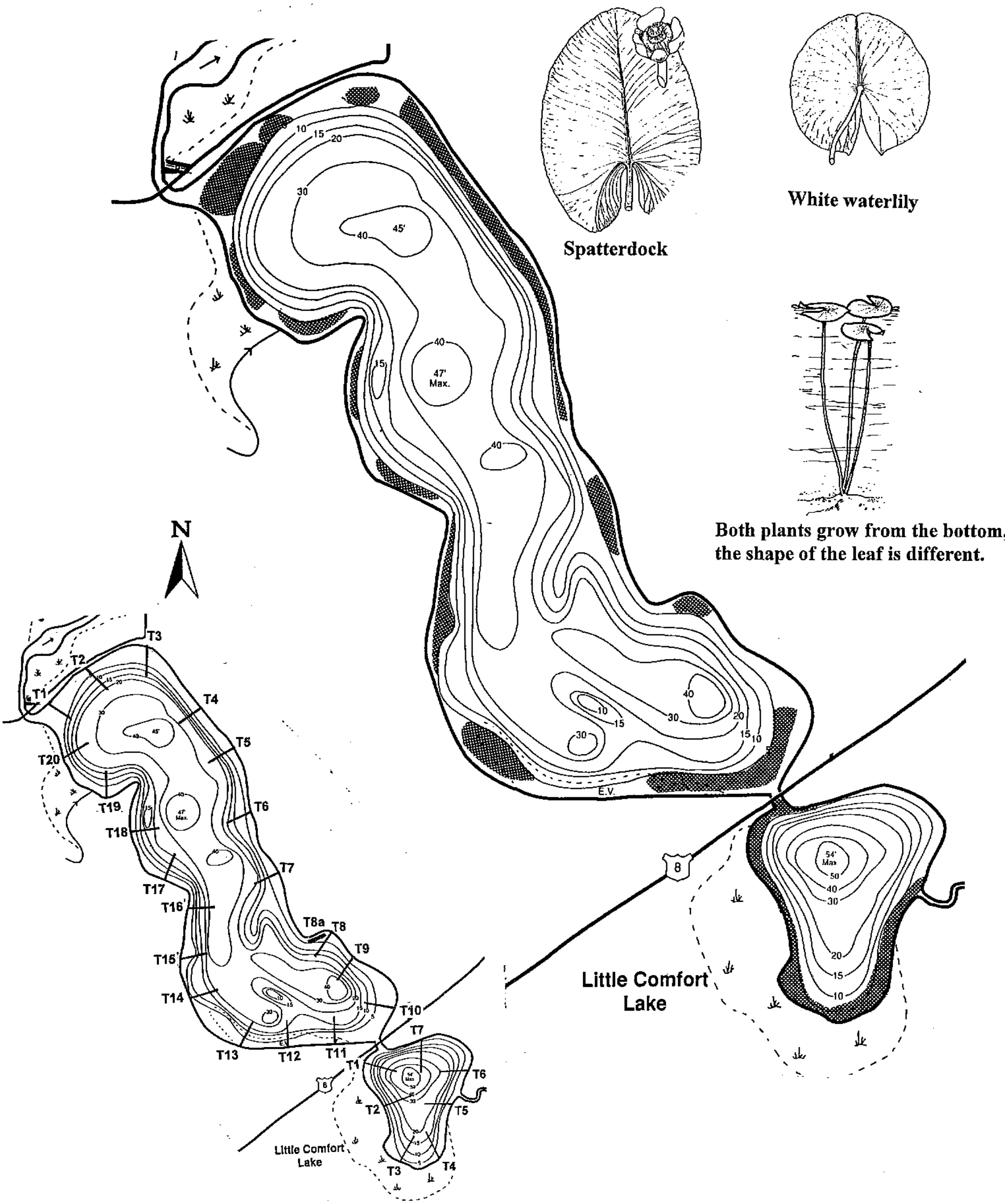


Figure 21. White waterlily and spatterdock coverage on Big Comfort, 8.31.98 and Little Comfort Lake, 9.21.98.

Fish

Both Big Comfort and Little Comfort Lakes fish survey results show that both lakes are good panfish producers. Both lakes have management classification as Centrarchid-largemouth bass lakes. Individual lake survey results are described below.

Big Comfort Lake

A lake survey was conducted on Big Comfort Lake, June 18-22, 1990. It was found at that time that both the northern pike population (as evidence by the solid year classes) and the panfish population were self sustaining populations, but the walleye population was being supported by stocking (since 1986).

The gill net sampling results show that all fish species sampled excluding yellow perch and white suckers are below the statewide median, the yellow perch were 1.6 times the statewide median and white suckers are about equal with the statewide median. Trapnet sampling results tell a different story. All fish, except common carp and white crappie, are above or equal to the statewide median. The bluegill population was six times greater than the statewide median and black crappies were twelve times.

Fish have been stocked in Big Comfort Lake since 1908. The fish species include (these names were taken directly off state stocking records) bass, crappie, pike, nor. pike, sunfish, L.M. bass, and walleye. These early stockings procedures indicate that cans, fry or fingerlings of fish were added to water bodies. Fish also have been removed from Big Comfort since the 1930s. These fish were mainly roughfish.

Little Comfort Lake

A lake survey was conducted on Little Comfort Lake during the same week as the survey on Big Comfort Lake (June 18-20, 1990).

Gillnet results show that the fish sampled were below the state median except for yellow perch which were 1.7 times the statewide median. Trapnet results repeat almost the same trends, except some species were closer to the statewide median. Bluegill and black crappies were 1.8 and three times the statewide median respectfully.

Table 25. Gillnet and trapnet catch summaries for Big and Little Comfort Lakes. Results are shown in number of fish per set.

Gillnet data	Big Comfort				Little Comfort		
	7.20.55	6.19.80	6.17.85	6.19.90	6.20.80	6.17.85	6.20.90
Bowfin		0.17	0.33		2.00	0.33	
Northern pike	1.33	4.83	6.17	3.50	5.00	4.33	2.67
Carp					0.67		
Golden shiner		0.17					
White sucker	0.33	0.50	0.67	1.00			
Black bullhead	3.83	5.17	4.83	0.17	16.67	12.67	0.67
Yellow bullhead			0.83			1.00	
Brown bullhead		7.17	0.83		0.33		
Bluegill	0.33	0.17	0.33	0.33		5.00	0.67
Largemouth bass			0.33				
White crappie	3.67	3.17	7.67	0.83		4.67	
Black crappie	0.83	1.33	0.33	4.50	1.67	0.67	1.67
Yellow perch	22.70	20.50	20.17	16.50	1.33	2.67	5.00
Walleye	0.17	0.17	1.17	0.83			

Trapnet data	Big Comfort				Little Comfort		
	7.20.55	6.19.80	6.17.85	6.19.90	6.20.80	6.17.85	6.20.90
Bowfin		1.25	1.75		2.50	1.25	0.50
Northern pike					0.25	0.25	0.75
Carp	0.50		0.25	0.50	0.25		1.25
Golden shiner		0.25					
White sucker	0.75					0.75	
Black bullhead	1.75	0.25	1.25	3.75	1.25	1.25	1.00
Yellow bullhead	0.50		3.25	3.00		1.00	
Brown bullhead	1.00		0.25		1.00	1.50	0.25
Hybrid sunfish		0.25	2.25	4.50	2.25		
Green sunfish	0.25	6.75		0.75	5.25		0.50
Pumpkinseed	0.25	5.00	0.75	4.00	6.25	1.25	2.25
Bluegill	2.25	1.25	14.25	199.50	24.00	53.75	45.75
Largemouth bass			0.25	0.75			0.25
White crappie	5.50	0.25	7.00	0.50	0.75	7.50	
Black crappie	1.25	0.75	20.50	64.75	4.50	5.75	15.50
Yellow perch		0.50	0.25	0.75			0.25
Walleye	0.25						

Table 26. Fish removal efforts on Big Comfort. Results are shown in pounds except for largemouth bass and bluegill which are shown in number of adults.

Year	Multiple Species	Carp	Bullheads	Dogfish	Suckers	Largemouth bass	Bluegills
1938-39	2,295						
1945-47	28,330					7*	
1947-48		32,400				8*	
1949-50		300					
1952-53		16,200					
1953-54		3,900					
1954-55			600				
1955-56		3,500			150		
1956-57		220					
1957-58		3	8,707	279			
1958-59		150		100			
1959-60		1,900		29			
1960-61		3,674	3				
1961-62		750	675				
1990						26*	2,965*
Total	30,625	62,997	9,985	408	150	41	2,965

* individual fish, not pounds of fish

II.3. Discussion

II.3A. Assessment of the Project's Resource Water Quality

Watershed Assessment

Both Big Comfort and Little Comfort Lakes have very large watersheds. Wetland and stream sampling results show elevated levels of phosphorus for some of the subwatersheds and Subwatershed 5 in particular. Subwatershed 5 is an important phosphorus source. There are also elevated water runoff volumes from Subwatershed 2 compared to other subwatersheds (see Figure 12, p. 39 for location of subwatersheds).

However, a question we have is why does Subwatershed 5 have high phosphorus levels today? Farmland acreage has been declining since the 1940s. In the Big Comfort Lake water there are currently only 4 farms in the watershed. The Little Comfort Lake watershed has several farms as well, but no farms after School Lake.

We suspect that nutrient buildup starting over 130 years ago has set the stage for nutrient leaching from upland and wetland soils. A sequence of events in the last decade or so appears to have resulted in above average phosphorus loading from the wetland in Subwatershed 5. A timeline and sequence of factors is shown in Table 27.

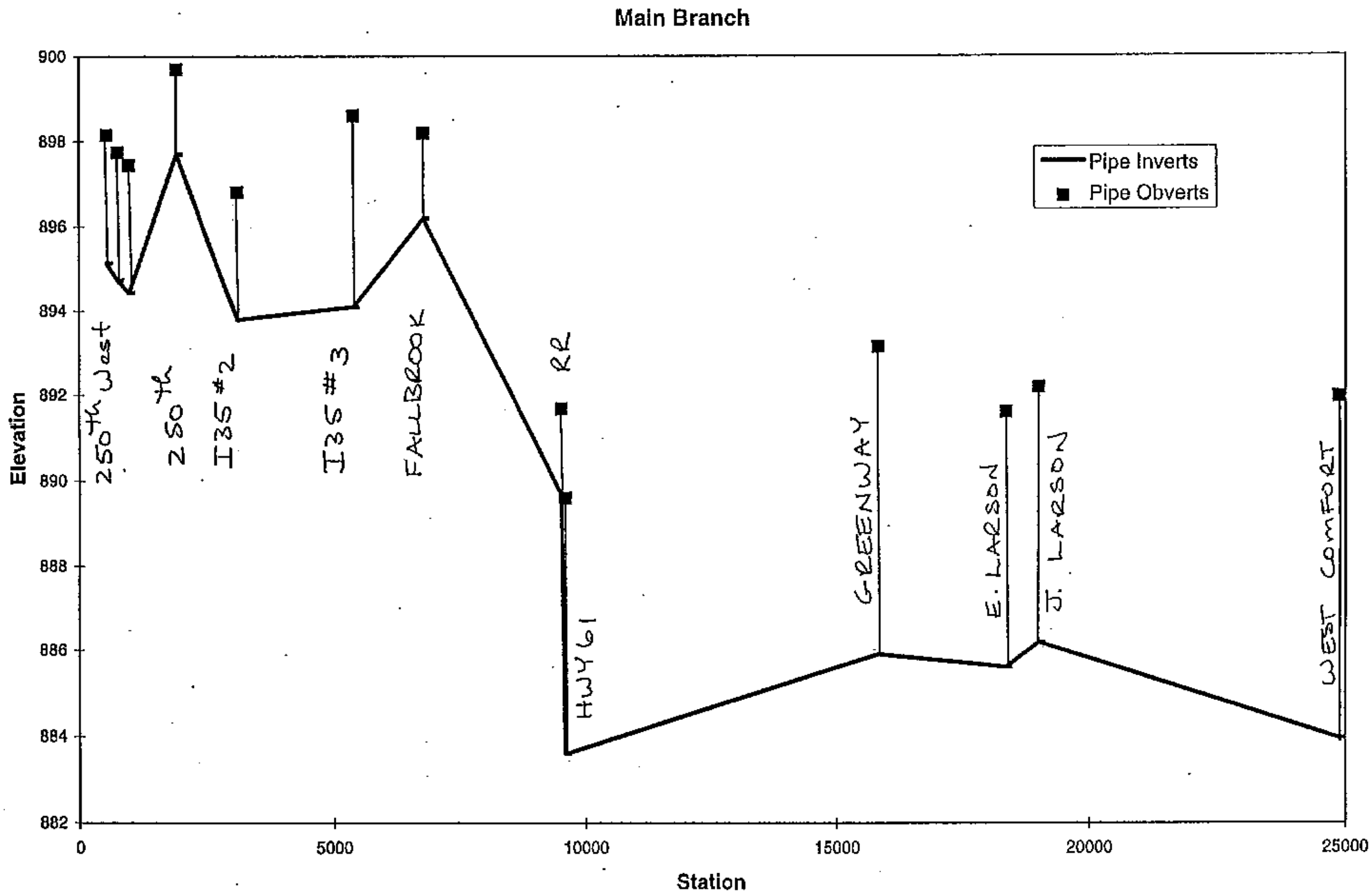
To reduce elevated nutrient concentrations we recommend management practices that reduce phosphorus from nutrient leaching resulting from previous accumulation in upland and wetland soils.

Table 27. Timeline and sequence of factors influencing water quality in Big Comfort Lake

1965	240 ac of concrete put down with new Hwy 8 construction and interchange with 35W.
1970s	Sod farming occurring in "Shallow Pond". Fertilization rates are unknown.
1988	Culvert is replaced in JD1, (J Larson location, shown in figure on p. 62) it is smaller and 1 foot higher in elevation than the old culvert. Residents say it acts like a dam and backs up water in the ditch.
1988-89	Drought-like conditions -- little runoff, rainfall low.
1989	Comfort Lake has some of the best water quality in Chisago County.
1990	Wet year coming after 3 dry years -- generally produces elevated phosphorus loading from wetlands.
1992	Exposed peat piles are produced as a result of construction activities. Area residents who farm are getting less hay every year from "Shallow Pond" due to encroaching wetness from the increasing amounts of water in the ditch. Landowners observe increase flooding on their property.
1993	Walmart construction proposed in Forest Lake. Wet year coming off a dry year -- assume significant wetland leaching coupled with increase runoff from new impervious surfaces.
1994	MPCA Lake Assessment done on Comfort Lake. Walmart fills in 8 acres of wetland for store site. Mitigation ponds built on Elden Larsen farm. Culvert replaced on Sunrise River.
1997	Clean Water Partnership project starts.
1998	Monitoring results show phosphorus levels are moderate in subwatersheds that feed into Shallow Pond. However phosphorus levels and nutrient loads are high at the outlet of Shallow Pond.
1999	Clean Water Partnership report is prepared. It is concluded that increased runoff from commercial and residential development coupled with a blockage in the ditch resulted in greater saturation in the shallow pond wetland complex. This produced increased phosphorus leaching from the shallow pond wetland resulting in an increase in phosphorus loading to Big Comfort Lake probably accounting for excessive algae blooms that were first observed in 1994.

(Additional timeline information was prepared by Ken Banta, a Watershed District Manager, and is located in the Appendix) Ken Banta, owns one of the four remaining farms, and is a lifelong resident of Wyoming Township.

The watershed assessment raised several questions. For example, was placement of a culvert in JD 1 a contributing factor that has resulted in excessive phosphorus release into the main branch of JD 1/Sunrise River? Is the culvert invert at the J. Larson location (map shown below) acting as a dam to back water up in JD 1 causing an increase in wetland saturation and ultimately phosphorus release from the wetland soils? It would appear that actions that could be taken to minimize ponding in the main branch could help reduce phosphorus concentrations in the ditch and lower phosphorus loading to Big Comfort Lake.



Main branch profile. (From Beduhn, R. 1997. Judicial Ditch No. 1 Inspection. Prepared for Forest Lake WMO, by HDR Engineers, Minneapolis, MN.)

Lake Assessment

Comfort Lake has nuisance blue-green algae blooms in July and August and that not only is unappealing, but may favor rough fish in the long run and adversely impact the sport fishery. The lake has another nuisance, a plant, called curlyleaf pondweed (*Potamogeton crispus*). In some lakes, when this exotic plant dies back in June, wind action piles dead plants up on resident shorelines. However, there is another potential problem. It can be a significant internal lake nutrient source as well. This is a plant to watch. A spring plant survey would help to characterize the status of curlyleaf pondweed.

One of the findings of this study showed elevated bottom lake phosphorus concentrations were present (compared to surface concentrations) indicating internal loading was occurring. It could be from lake sediments. We estimate internal loading from lake sediments to be 700 kg/yr for Big Comfort and 120 kg/yr for Little Comfort (based on an average lake sediment phosphorus release rate of 8 mg-P/m^2/day for 100 days).

Resident observations of summer algae blooms are supported by water chemistry and secchi disc data. We did not find substantial lake data for years prior to 1994. Therefore it is difficult to determine lake trends.

Lake Resident's Survey Results

A mailed questionnaire survey was sent to lake residents on Big and Little Comfort Lakes. A summary of survey results are shown in the Appendix.

Aesthetics ranked as the most enjoyable aspect of the Comfort Lakes and the biggest perceived problem was water quality.

II.3B. Assessment of pollutant loads

Pollutant loads can be figured by a number of different methods. We used two methods. The first was based on monitoring data and the second was based on land use nutrient export coefficients.

Nutrient loading from the two methods is shown in Table 28.

Table 28. Phosphorus loading to Big and Little Comfort Lakes based on land use with nutrient export coefficients and on monitored flows from April through September 1998 and extrapolated to a whole year. Estimated flows are based on best professional judgement. There are higher flows for Big Comfort because there are more impervious surfaces than Little Comfort.

Method 1: Measured Flows and Sampling

Little Comfort Lake: Site 3 Loading Data	Flow (ha-m)	Total Phos Conc (ppb)	Phosphorus Load (lbs)	Phosphorus Load (kg)	Big Comfort Lake: Site 5 Loading Data	Flow (ha-m)	Total Phos Conc (ppb)	Phosphorus Load (lbs)	Phosphorus Load (kg)
April - Sept (6 mon, measured)	1.61	123	434	197	April - Sept (6 mon, measured)	5.66	263	3,269	1,489
Jan-Mar (3 mon, estimated)	0.20	110	48	22	Jan-Mar (3 mon, estimated)	1.50	120	396	180
Oct-Dec (3 mon, estimated)	0.20	110	48	22	Oct-Dec (3 mon, estimated)	1.00	120	264	120
Watershed (year)	2.01	120	530	241	Watershed	8.16	231	3,929	1,789

Method 2: Land Use and Export Coefficients

Little Comfort Lake	%	Acres	Export Coefficient* (lbs/ac)	Phosphorus Load (lbs)	Phosphorus Load (kg)	Big Comfort Lake	%	Acres	Export Coefficient (lbs/ac)	Phosphorus Load (lbs)	Phosphorus Load (kg)
Forest	9.1	868	0.09	78	35	Forest	7.6	906	0.09	82	37
Marsh	38.0	3,626	0.09	326	148	Marsh	50.4	6,051	0.09	544	247
Pasture	7.0	668	0.27	180	82	Pasture	5.6	672	0.27	181	82
Cultivated	27.9	2,662	0.90	2,396	1,087	Cultivated	21.8	2,622	0.90	2,360	1,071
Urban	18.0	1,717	0.60	1,030	467	Urban	14.6	1,746	0.60	1,048	475
Watershed	100	9,541	0.42**	4,010	1,819	Watershed	100	11,997	0.35**	4,215	1,912

*Export coefficients from Wisconsin Lake Model Spreadsheet 3.0
**Estimated from phosphorus load and watershed acreage.

For Little Comfort Lake, measured loads were only 13% of the estimated loads based on export coefficients. However, for Big Comfort measured loads were about 93% of estimated loads based on export coefficients. The large number of lakes in the Little Comfort watershed are serving as phosphorus sinks at the present time.

II.3C. Resource water quality goals

Comfort Lake is located in the North Central Hardwood Forest (NCHF) ecoregion (Table 27). The state's aquatic ecoregion framework is based on land use, soils topography, and natural vegetation. These seven regions (shown in Figure 22) were determined by integrating key geographic variables to reveal areas in the state with similar characteristics. The NCHF region represents a transition between northern forested areas and southern agricultural areas.

In the NCHF ecoregion the typical values for total phosphorus concentrations range from 23-50 µg/l and transparency measured with a secchi disc from 1.5 to 3.2 meters (approximately 5-10 feet) for minimally impacted lakes in this region. Streams generally have a phosphorus concentration of around 145 ppb.

The slightly elevated summer average phosphorus levels (40 and 58 µg/l) and summer average transparency readings 4.3 and 3.9 feet for Big and Little Comfort Lake exceed the values for minimally impacted lakes for the NCHF ecoregion.

The phosphorus criteria for lakes in the NCHF ecoregion for most sensitive uses is <40 µg/l. Most sensitive uses are uses that an increase in this phosphorus level can change the trophic status of the lake. Comfort Lake's most sensitive uses would be primary contact recreation and aesthetics. To fully support aesthetic and swimmable uses, Comfort Lake should exhibit "impact swimming" conditions less than 10 percent of the time. ["Impact swimming" was a term inserted by the Lake Association as they interpreted EPA's water quality criteria based, in part, on water clarity. Conditions were worse in 1998.] To reach this goal for a NCHF lake, the total phosphorus concentration according to Minnesota Pollution Control Agency (MPCA) criteria must be less then 40 µg/l.

<u>The status of Comfort Lake in 1999 was eutrophic.</u>

Table 29. Summer average water quality characteristics for lakes in two ecoregions, as noted in Descriptive Characteristics of the Seven Ecoregions in Minnesota, by G. Fandrei, S. Heiskary, and S. McCollar. 1988. Minnesota Pollution Control Agency. Comfort Lake is in the North Central Hardwood Forest ecoregion.

Parameter	Northern Lakes & Forests	North Central Hardwood Forests	Big Comfort Lake	Little Comfort Lake
Total phosphorus (ppb)	14-27	23-50	40	58
Chlorophyll a (ppb)				
mean	<10	5-22	11	15
maximum	<15	7-37	24	37
Secchi disc				
feet	8-15	4.9-10.5	4.3	3.9
meters	2.4-4.6	1.5-3.2	1.3	1.2
Total Kjeldahl Nitrogen (mg/l)	<0.75	<0.60-1.2	1.1	1.2
Nitrite & Nitrate N (mg/l)	<0.75	<0.01	<0.01	<0.01
Alkalinity (mg/l)	40-140	75-150	172	164
Color (Pt-Co units)	10-35	10-20	--	--
pH (SU) 7.2-8.3	8.6-8.8	8.2-9.0	8.1	7.9
Chloride (mg/l)	<2	4-10	--	--
Total Suspended Solids (mg/l)	<1-2	2-6	--	--
Total Suspended Inorganic Solids (mg/l)	<1-2	1-2	--	--
Turbidity (NT)	<2	1-2	--	--
Conductivity (umhos/cm)	50-250	300-400		
TN:TP Ratio	25:1-35:1	25:1-35:1	36:1	48:1

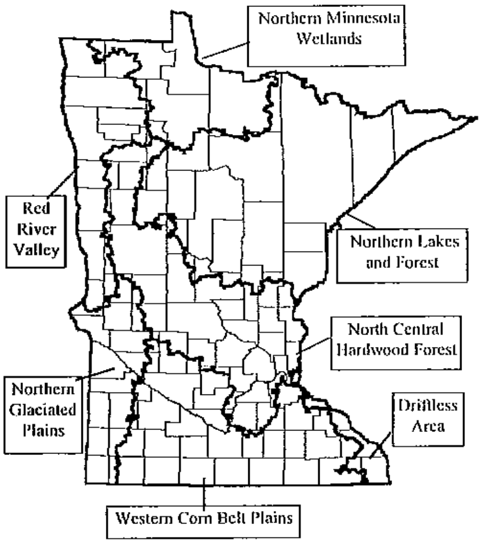


Figure 22. Minnesota ecoregion.

II.3D. Target Conditions to Meet Water Quality Goals

Considering the current nutrient status of Comfort Lake and the relatively good transparency in early summer a goal of around 40 µg/l should be achievable. Thus the quantitative goal for the project is to reduce phosphorus concentrations to <40 µg/l. Reductions of the lake phosphorus concentrations below 40 µg/l should result in water quality improvements as measured by chlorophyll a (algae abundance) and secchi disc transparency. Specific lake target conditions are shown in Table 30. If these goals are reached, the transparency for Comfort Lake, in the month of August is predicted to increase from 3.0 to 6.0 feet.

If the phosphorus levels could be lowered at least to the 30-40 µg/l range, there would be less nutrients to contribute to heavy algal blooms now experienced in mid to late summer on Comfort Lake. Under these more favorable conditions different species of aquatic plants would proliferate and may indirectly help gamefish. The increased visibility of the lake water would benefit the predator gamefish which rely on sight to capture their prey.

Table 30. Target conditions.

	Big Comfort		Little Comfort	
	Existing Conditions	Target	Existing Conditions	Target
Water clarity (May-Sept Average)	4.3	7.0	3.9	5.0
Total Phosphorus (ppb)	40	30	58	40
Aquatic Plant Coverage	20%	40%	20%	40%

Using Lake Models to Determine Phosphorus Reduction Requirements to Meet Goals

We developed a lake model to predict existing conditions. We have used two methods to determine nutrient loading to the Comfort Lakes: nutrients associated with measured flows and land use export coefficients. Lake model inputs using these two methods are shown in Table 31 (modeling details are found in Addendum D).

Table 31. Lake phosphorus model input parameters. Models were run using the WILMS 2.0 spreadsheet.

	Big Comfort Lake	Little Comfort Lake
Lake size (acres)	219	37
Mean depth (feet)	19.1	17.8
Volume of Lake (ac-ft)	4,183	659
Watershed size (acre)	21,575	9,541
Watershed runoff (inches)	8.3 (35%)	3.2 (12%)
Precip - Evap	0	0
Method 1: Flows and Sampling Watershed Inputs	2,117 kg	241 kg
Method 2: Land Use Export Coefficient Watershed Inputs	1,912 kg	1,819 kg
Point Source to Big Comfort from Little Comfort	117 kg	--
Septic Tank Loading	10 kg	2 kg
Rainfall	24 kg	4 kg
Observed Spring Total Phosphorus (ppb)	24	33
Observed Growing Season Phosphorus (ppb)	40	58
Lake Phosphorus Model Prediction (method 1)	50*	54**
Lake Phosphorus Model Prediction (method 2)	47*	129*

* Walker Reservoir model, 1987
** Walker Lake model, 1977

Model results show that for Big Comfort Lake, Method 2 and the Walker Reservoir model has the closet fit to the observed lake concentration. For Little Comfort Lake, Method 1 and the Walker Lake model gives the closest fit to the observed lake concentration. Based on modeling results we conclude that Big Comfort Lake either has lower phosphorus concentrations than expected or we overestimated watershed phosphorus inputs. Lowering the watershed phosphorus input by 300 kg (a 16% decrease) then gives a model prediction close to the observed value of 40 ppb. For Little Comfort Lake, the estimated loading based on flows and stream sampling produces a better lake model predication than using export coefficients.

Modeling Results for Different Lake Conditions

To achieve the in-lake phosphorus concentration goal of 30-40 ppb, nutrient input reductions are necessary. A summary of these reductions is shown in Table 32. The nutrient reductions come from the watershed and from in-lake sources.

Projects that would reduce phosphorus inputs are described in the next section, the Implementation Plan.

Table 32. Existing nutrient inputs based on monitored flows and nutrient sampling and estimated future nutrient inputs after projects have been implemented.

	BIG COMFORT LAKE				LITTLE COMFORT LAKE		
	Existing Budget (kg phosphorus)		Future P Budget Needed to Reach 35 ug/l (kg/yr)		Existing Budget (kg phosphorus)		Future P Budget Needed to Reach 35 ug/l (kg/yr)
	6 month	Year			6 month	Year	
Sub 1	27	33	31	Bone Lake	48	59	50
Sub 2	103	121	65	Sub 3	149	182	122
Sub 4	233	268	200	Subtotal	197	241	172
Sub 5	1,155	1,397	560				
Subtotal	1,518	1,819*	856				
Little Comfort	--	117**	80***				
Direct Drainage	--	214	107	Direct Drainage	—	45	22
Subtotal	--	2,150	1,043	Subtotal	197	286	194
Septic tanks	--	10	10	Septic tanks		2	2
Rainfall	--	24	24	Rainfall		4	4
Subtotal	--	34	34	Subtotal		6	6
Total	--	2,218	1,077	Total		292	200

*Flow for rest of year was 2.5 hectometers at 120 ppb = 300 kg.
**Little Comfort phosphorus concentration = 58 ppb x 2.01 hectometers = 117 kg
***Little Comfort phosphorus concentration reduced from 58 ppb to 40 ppb.

II.4. Conclusions

Important Findings of This Study

- Watershed area to Big Comfort Lake is 88 times larger than the surface area of Big Comfort Lake.
- Watershed area to Little Comfort Lake is 257 times larger then the surface area of Little Comfort Lake.
- Both Big and Little Comfort Lakes are drainage lakes, with large watersheds. They are heavily influenced by watershed inflows.
- Runoff in the direct drainage areas around Big and Little Comfort Lakes are an important nutrient source to control.
- The runoff into Little Comfort Lake has high volume and low phosphorus concentrations. The resulting amount of phosphorus delivered to Comfort Lake is moderate, but high enough to account for nuisance summer algae blooms.
- In recent years, in the Big Comfort Lake watershed, the increase in impervious surfaces has increased the amount of stormwater runoff, while not greatly increasing the amount of phosphorus. However, the increased volume of stormwater coupled with culverts that hold back flow, apparently has increased saturation in a large wetland area in what is called Shallow Pond. The increase in saturation results in additional phosphorus leaching from the wetland peat. This wetland area then exports elevated amounts of phosphorus that are carried into Big Comfort Lake.
- Over 50% of the lots in the Big Comfort shoreland fringe around the lake have a native buffer strip.
- Lake improvement projects will address watershed, shoreland, and lake areas.

Approach for Improving Big and Little Comfort Lake

Comfort Lake has summertime phosphorus concentrations high enough to produce nuisance blue-green algae blooms that turn the water green. The lake is slightly clearer than what we would expect based on summer average phosphorus concentrations.

We have calculated, based on this study, that excess phosphorus comes from the watershed and from lake sources. High lake nutrient concentrations produce summertime nuisance algae blooms. We have a plan for reducing nuisance algae blooms.

The hypothesis for reduction of nuisance algae blooms is that a dominant macrophyte community will suppress nuisance blue-greens if there is enough macrophyte coverage. Several mechanisms appear to be involved that make this possible. Periphyton can compete with open water algae for nutrients. Secondly, macrophytes have a method for transferring oxygen to the rhizosphere (root zone). This helps the plant to assimilate nutrients and it helps the lake because aerobic conditions suppress phosphorus release from the sediments.

Under existing conditions in Comfort Lake a diverse plant community is present, but it is limited.

If Comfort Lake clarity could increase, the odds are the macrophyte community would increase, at the expense of algae.

For Comfort Lake to attain long term water clarity, a diverse macrophyte community needs to be established. Dr. Brian Moss of the University of Liverpool, England has described the mechanism needed to be put in place to switch a lake from algae domination to aquatic plant domination. The Comfort Lake project is to be geared to implement these reverse switches.

Our goal is to maintain a macrophyte community that colonizes about 40% or more of the lake bottom. Dr. Dan Canfield has observed that Florida lakes with 40% or more macrophyte coverage have clear water conditions (Canfield and Hoyer 1992). A small data base on eight lakes in Minnesota and Wisconsin compiled by Steve McComas (Blue Water Science) finds a similar relationship.

For a theoretical coverage of 40% of the Comfort Lake bottom, plants would need to colonize to a depth of about 14 to 15 feet. This is achievable if water transparency increases. To improve water transparency, phosphorus reductions are necessary.

III. Implementation Plan

III.1. Implementation Plan Goals

The objectives of the Comfort Lake implementation plan are summarized in Table 33.

Table 33. Goals for the Comfort Lake watershed.

Topic Area	Existing Conditions	Goals
Nutrients	Summer average phosphorus concentration is 40 ppb for Big Comfort and 58 ppb for Little Comfort Lake.	Reduce summer average phosphorus to 30 ppb in Big Comfort and to 40 ppb in Little Comfort.
Water Clarity	Summer average is 4.3 feet for Big Comfort and 3.9 feet for Little Comfort Lake.	Maintain summer average transparency of at least 6 to 7 feet.
Algae	Algae blooms are increasing in duration.	Reduce summer algal blooms.
Weeds	Nuisance growth of curlyleaf pondweed occurs and native plant coverage is low.	Reduce nuisance acreage by 50%. Maintain diverse native aquatic plant community that covers 40% of bottom area.
Fish	Average to above average northern pike community, with high carp numbers.	Add bass and maintain predator control of forage fish through catch and release.
Wildlife	Typical Chisago County diversity.	Improve wood duck habitat and shoreline areas to encourage other bird species and discourage geese nesting.
Water Use Conflicts	Moderate boat traffic and lake use	Maintain moderate boat traffic and reasonable hours.

III.2. Identification of Priority Management Areas

Four priority management areas have been identified in the Comfort Lake watershed (Figure 23):

1. Shoreland areas (*direct drainage to lake has no ponding*)
2. Areas with new residential development (*erosion control at construction sites is essential*).
3. Subwatershed 5 (*wetland complex is significant source of phosphorus*).
4. Subwatershed 1 and 2 (*commercial development is source of high runoff volumes*).

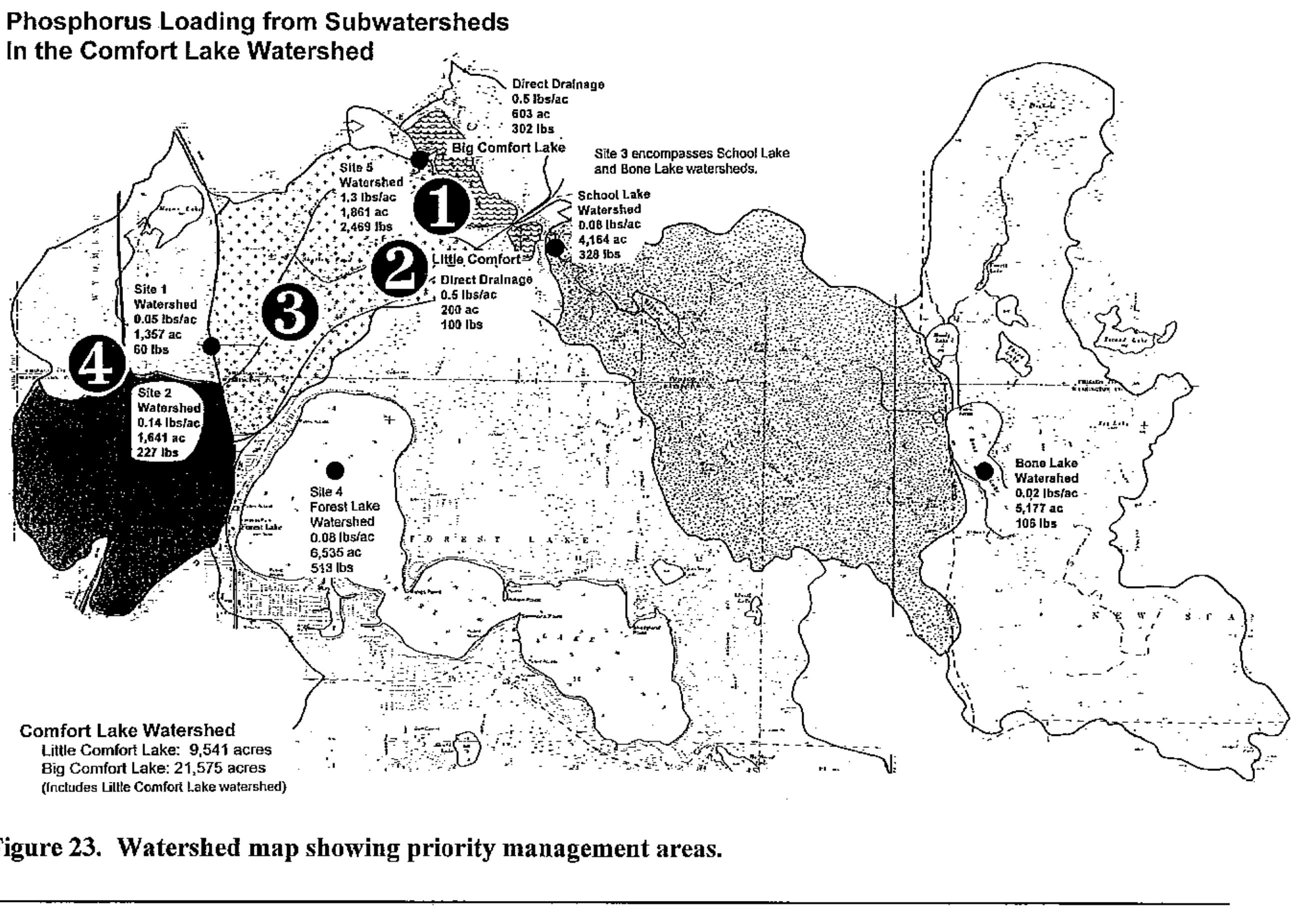


Figure 23. Watershed map showing priority management areas.

III.3. Best Management Practice (BMP) Alternatives and Analysis

III.3A. Evaluation and Costs of the Initial List of Possible Alternatives of BMPs

An initial list of possible alternatives that if implemented would allow Comfort Lake to maintain and sustain goals is described in Table 34.

The cost includes cash that would be required as well as in-kind costs.

Table 34. Initial project list of potential alternatives.

Project	Description	Cost
A.. Implement stormwater BMPs for commercial development in Subwatersheds 1 and 2.	With residential and commercial development ongoing in these 2 critical subwatersheds it is important that stormwater runoff water quality projects continue to be implemented.	$90,000
B. Implement, where feasible, infiltration and runoff rate controls in all subwatersheds.	Reducing the volume of runoff by 10% through small-scale infiltration efforts could reduce flooding in Subwatershed 5 and reduce phosphorus release from saturated wetland sediments.	$100,000
C. Lower culverts in Sunrise River in Subwatershed 5.	Two culverts apparently are set too high in Subwatershed 5. They may be acting like a dam. Lowering culverts may reduce water back-up and therefore reduce flooding or wetness in the Shallow Pond wetland complex.	$7,000
D. Install linear ditch aeration in Subwatershed 5 (pending results of other linear ditch systems).	Aerating slow moving ditch water high in phosphorus and iron may precipitate iron which in turn would serve to scavenge dissolved phosphorus and make it biologically unavailable.	$20,000
E. Promote shoreland restoration emphasizing native plant conditions.	Native landscaping and lakescaping improve runoff water quality and help attract wildlife. Buffer strips and shoreland vegetation reduce nutrient loading to the Comfort Lakes.	$27,000
F. Maintain onsite systems.	Septic systems are mostly in good working order. Maintenance and ongoing education should help to keep them from being either an environmental health problem or a water quality problem.	$8,200
G. Remove roughfish through the use of carp traps and commercial fishing.	Use commercial fishermen to fish down the carp population in both Comfort Lakes. Carp may be limiting aquatic plant growth in Big Comfort Lake. Reducing carp may improve plant coverage.	$9,000
H. Install carp barriers to reduce carp movement into Judicial Ditch 1 (Sunrise River).	If carp can be fished down to lower numbers, carp barriers could inhibit movement into the Sunrise River for spawning, helping to keep carp recruitment down in the Comfort Lakes.	$1,200
I. Conduct lake soil testing to set-up contingency plan for Eurasian watermilfoil invasion.	Milfoil has not been found at the present time. Lake soil testing will delineate areas that could produce nuisance growth. Lake mapping will then help determine a management approach and level of effort needed to control nuisance growth.	$5,500
J. Develop program to promote native plants and reduce spraying. Transplant macrophytes if they don't come back after fish removal.	Native plants need to cover more area then they presently do to sustain good water quality.	$18,000
K. Maintenance dredging around culverts, especially off Highway 8.	Maintenance dredging around culverts at Highway 8 will help maintain water flow from Little to Big Comfort. Other culverts need maintenance also.	$3,900
L. Whole lake alum project (reserve project to be implemented if needed)	An alum application in both Little and Big Comfort Lakes would reduce phosphorus loading from lake sediments. This is a reserve project meaning it may not be needed if other management projects achieve water quality improvements. It would be scheduled for Year 4 or 5, putting it in Part 2 of a Phase II program.	$103,000
M. Establish lake outlet elevation	Lake residents have asked for a permanent outlet setting. This is currently under construction.	$0
N. Promote large-scale infiltration	Infiltration would reduce stormwater volume.	$300,000
O. Raise culverts, reflood "shallow pond"	Reflooding Shallow Pond would require the purchase of several parcels.	$800,000
P. Add stream dosing station at site 5	Stream dosing is expensive, requires ongoing maintenance.	$250,000
Q. Divert Sunrise River/JD 1 around Big Comfort Lake	Bypass Big Comfort Lake by digging a new channel that diverts flow into the outlet area of Big Comfort Lake.	$175,000

III.4. BMP Selection and Justification

III.4A. Selected BMP package: Rational and Justification

Watershed Projects

1. Implement stormwater BMPs for commerical development in Subwatersheds 1 and 2.
2. Implement, where feasible, infiltration and runoff rate controls in all subwatersheds.
3. Lower culverts in Sunrise River in Subwatershed 5.
4. Install linear ditch aeration in Subwatershed 5 (pending results of other linear ditch systems).

Shoreland Projects

5. Promote shoreland restoration emphasizing native plant conditions.
6. Maintain onsite systems.

Lake Projects

7. Remove roughfish through the use of carp traps and commercial fishing.
8. Install carp barriers to reduce carp movement into Judicial Ditch 1 (Sunrise River).
9. Conduct lake soil testing to set-up contingency plan for Eurasian watermilfoil invasion.
10. Develop program to promote native plants and reduce spraying. Transplant macrophytes if they don't come back after fish removal.
11. Maintenance dredging around culverts, especially off Highway 8.
12. Whole lake alum project (reserve project to be implemented if needed)

Education Program (described in Education Element)

- Promote pollution prevention by landowners on a watershed basis. This would target nutrient source reduction and be done through information and education programs.
- Community Education program which includes public access rules for Little Comfort Lake, fish limits for lakes, snowmobile trails, etc.
- Coordinate efforts of local and state agencies to enforce shoreline and lake rules and regulations

Ongoing Programs (already in place)

- Continued implementation and enforcement of surface water management plan in Wyoming Township.
- Intergrated water management policies through the Watershed District.
- Establish Ordinary High Water Level elevations for Big and Little Comfort Lakes and a maintenance program.
- Update stormwater management plan for Forest Lake.

Table 35. Rationale and justification of BMPs in the package.

Project	Rationale
Watershed Projects	
1. Implement stormwater BMPs for commercial development in Subwatersheds 1 and 2.	With residential and commercial development ongoing in these 2 critical subwatersheds it is important that stormwater runoff water quality projects continue to be implemented.
2. Implement, where feasible, infiltration and runoff rate controls in all subwatersheds.	Reducing the volume of runoff even 10% through small-scale infiltration efforts could reduce flooding in Subwatershed 5 and reduce phosphorus release from saturated wetland sediments.
3. Lower culverts in Sunrise River in Subwatershed 5.	Two culverts apparently are set too high in Subwatershed 5. They may be acting like a dam. Lowering culverts may reduce water back-up and therefore reduce floating or wetness in the Shallow Pond wetland complex.
4. Install linear ditch aeration in Subwatershed 5 (pending results of other linear ditch systems).	Aerating slow moving ditch water high in phosphorus and iron may precipitate iron which in turn would serve to scavenge dissolved phosphorus and make it biologically unavailable.
Shoreland Projects	
5. Promote shoreland restoration emphasizing native plant conditions.	Native landscaping and lakescaping improve runoff water quality and help attract wildlife. Buffer strips and shoreland vegetation reduce nutrient loading to the Comfort Lakes.
6. Maintain onsite systems.	Septic systems are mostly in good working order. Maintenance and ongoing education should help to keep them from being either an environmental health problem or a water quality problem.
Lake Projects	
7. Remove roughfish through the use of carp traps and commercial fishing.	Use commercial fishermen to fish down the carp population in both Comfort Lakes. Carp may be limiting aquatic plant growth in Big Comfort Lake. Reducing carp may improve plant coverage.
8. Install carp barriers to reduce carp movement into Judicial Ditch 1 (Sunrise River).	If carp can be fished down to lower numbers, carp barriers could inhibit movement into the Sunrise River for spawning, helping to keep carp recruitment down in the Comfort Lakes.
9. Conduct lake soil testing to set-up contingency plan for Eurasian watermilfoil invasion.	Milfoil has not been found at the present time. Lake soil testing will delineate areas that could produce nuisance growth. Lake mapping will then help determine a management approach and level of effort needed to control nuisance growth.
10. Develop program to promote native plants and reduce spraying. Transplant macrophytes if they don't come back after fish removal.	Native plants need to cover more area then they presently do to sustain good water quality.
11. Maintenance dredging around culverts, especially off Highway 8.	Maintenance dredging around culverts at Highway 8 will help maintain water flow from Little to Big Comfort. Other culverts need maintenance also.
12. Whole lake alum project (reserve project to be implemented if needed)	An alum application in both Little and Big Comfort Lakes would reduce phosphorus loading from lake sediments. This is a reserve project meaning it may not be needed if other management projects achieve water quality improvements. It would be scheduled for Year 4 or 5, putting it in Part 2 of a Phase II program.

DETAILS OF IMPLEMENTATION PROJECTS

1. Implement stormwater best management practices (BMPs) in Subwatershed 1 & 2

Commerical and residental development is occurring in this part of the watershed faster than in other parts. Examples of BMPs include:

- Enforcement of erosion control practices at construction sites
- Fertilizer controls
- Stormwater ponding

Costs

• Review ordinances and stormwater plans for consistency (40 hrs)	$4,000
• Update stormwater plan for a watershed-wide approach	$40,000
• BMPs to be implemented by developers as new development are built	---
	$45,000

In-kind: ongoing stormwater management pond installation $45,000+

2. Promote small-scale infiltration and rate controls in all subwatersheds

There is already substantial infiltration of precipitation in the subwatersheds. An average of 5 inches of runoff per year occurs although there is an average 28 inches of rainfall. An additional 10 to 15 percent of infiltration could make a difference.

Costs

10% goal (50 ac-ft) $1 ac-ft = $50,000 + (developer)

In-kind: mitigation/construction $50,000

3. Lower culvert in Subwatershed 5

The Sunrise River and Judicial Ditch #1 are no strangers to controversy. Documentation shows that one culvert at Hawk Meadow (J. Larson crossing) may be a foot higher than the original ditch bottom. This can create a water restriction at this point resulting in ponding influences on ditch water levels upstream.

If the culvert was lowered, ditch flow would move more efficiently to Big Comfort, possibly reducing ditch water levels in upstream (toward Highway 6) stretches.

Costs

• Backhoe rental	$3,000
• Culvert replacement	$3,000
• Street repair	$1,000
	$7,000

4. Install linear ditch aeration system in Subwatershed 5

Subwatershed 5 especially the "Shallow Pond" area is a significant phosphorus source and is a targeted area for nutrient reduction. An experimental technique that could reduce phosphorus loading to Big Comfort Lake from the ditched wetland is aerating the ditch.

Our monitoring results showed high iron and phosphorus in the slow moving ditch water.

Costs

• Bring power to the site (Greenway Ave)	$3,000
• Aeration equipment (3 hp compressor and airline)	$14,000
• Engineering (30 hrs)	$3,000
	$20,000

5. Shoreland restoration

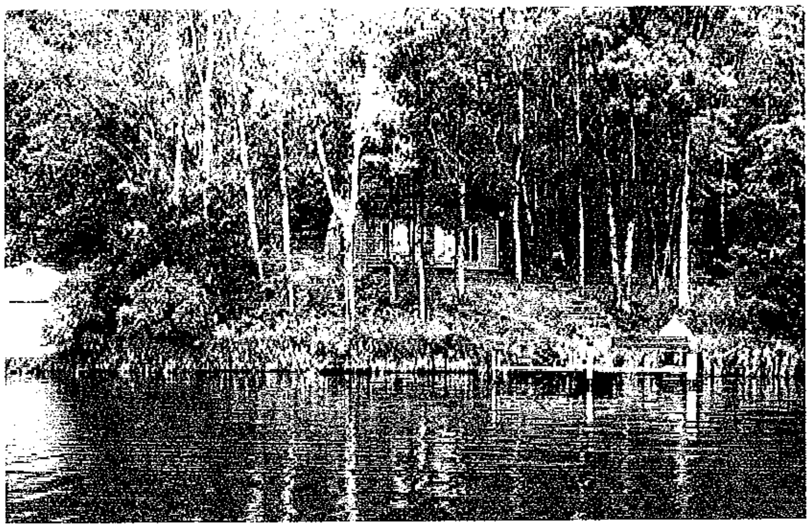
The shoreline of a lake is the last line of defense for removing pollutants from runoff. Overland runoff can be filtered one last time before it enters the lake.

Also the shoreland can be aesthetically pleasing and an attraction for interesting wildlife.

Several demonstration shoreland improvement projects could be installed on an annual basis over the next few years. Examples of the types of shoreland improvements are shown below.

Basic Shoreland Management Options

1. Naturalization: The easiest way to implement a natural shoreline setting is to select an area and leave it grow back naturally.



2. Accelerated Naturalization: To accelerate the naturalization, plant shrubs, wild flowers, or grasses into a shoreland area.

3. Reconstruction: This involves removing existing vegetation through the use of paper mats and/or mulching and planting a variety of native grasses, flowers, and shrubs into the shoreland area.

Shoreland Management Program Summary

Goal:	**Protect native shorelands and restore others.**		
Strategy:	1. Shoreland residents need to be aware of native shoreland benefits to the lake and environment.	2. Show how the first steps of naturalizing shorelands can be employed.	3. Make available lakescaping designs and mechanisms for shoreland restoration.
Action:	Conduct an initial shoreland inventory to characterize existing conditions. Produce informational materials and distribute to watershed residents. *Watershed District is leader.*	Produce informational material and set-up one demonstration site/year for three years. *Lake Association and Watershed District share lead.*	Produce informational material and set-up one demonstration site/year for three years. *Lake Association and Watershed District share lead.*
Evaluation:	Redo the shoreland inventory after three years.		
Analysis:	**Is program meeting shoreland management goal?**		
	Yes		No
Sustaining the Program:	**Continue program**		**Adjust strategies or projects**

Costs

- Demonstration projects $5,000/yr x 3 = $15,000

In-kind: $3,000/yr x 3 years = $9,000 (residents)
$1,000/yr x 3 years = $3,000 (State help)

6. Maintain onsite systems

The septic tank/soil absorption field has been one of the most popular forms of on-site wastewater treatment for years. When soil conditions are proper and the system is well maintained, this is a very good system for wastewater treatment. The on-site is the dominant type of wastewater treatment found around Comfort Lake today.

However, problems can develop if the on-site system has not been designed properly or well-maintained. Around Comfort Lake there are on-site systems that need maintenance and upgrades. At the same time, it is good practice to ensure that systems that are functioning adequately now will continue to do so in the future.

This project calls for an organized program to be developed that makes homeowners aware of all they can do to maintain their on-site systems.

A description of activities associated with the on-site maintenance program are described below:

- WORKSHOP
  A workshop should be scheduled for Comfort Lake residents to demonstrate the installation of a conforming septic system and the proper care and maintenance of a septic tank and septic system.

- SEPTIC TANK PUMPING CAMPAIGN
  Chisago County could work with the Comfort Lake Association in a coordinated campaign effort to get every septic tank associated with a permanent residence pumped every 2-3 years and seasonal systems pumped every 4-6 years in the Shoreland area to help reduce phosphorous loading to the septic system drainfield.

- ORDINANCE IMPLEMENTATION AND ONGOING REVIEW
  Continue enforcement of existing Township ordinance and ongoing education.

Costs

- Information and Education materials $5,200

7. Remove roughfish

Roughfish like carp, can contribute to poor water quality directly by excreting phosphorus into the water column and indirectly by uprooting desirable native plants in the pursuit of food.

Carp are present in Comfort Lake, but the size of their population is unknown. Test netting under the ice by commercial fishermen would help characterize the carp population. If the population is high, additional netting for control should occur. A high population would be about 50,000 pounds or 200 pounds per acre. At these levels, carp can have an adverse impact on water quality (McComas 2000).

Costs

- Trap construction & installation $3,000

2 yr @ $3,000/yr = $6,000

$9,000

8. Install carp barriers

To prevent the easy movement of carp back into the Sunrise River/JD #1 a carp barrier or a carp trap consisting of either a one way gate or a trap could be installed at the Bridgeport inlet. It would be non-clogging and prevent carp from leaving Comfort Lake to go up into the ditch to spawn and feed. Likewise a carp trap could be placed at the Little Comfort inlet area, especially during the carp spawning season.

Costs

$600/barrier x 2 = $1,200

9. Plan for milfoil invasion

Eurasian watermilfoil is an exotic aquatic plant that can grow to nuisance conditions and, in some cases, crowd out more desirable native plants. Because lakes in the area have milfoil, it is likely it will be introduced to Comfort Lake in the future.

A 3-step contingency plan is presented below.

Eurasian Watermilfoil Management Program Summary

Goal: **If Eurasian milfoil appears in Comfort Lake, use a 3-step program for control.**

Strategy:	1. Reduce watershed nutrient inputs to reduce nuisance milfoil growth and to allow natives to be more competitive.	2. Manage nuisance EWM patches with small-scale projects	3. Enhance natural EWM control in the lake using the weevil
Action:	Characterize watershed nutrient sources; characterize lake sediments; install nutrient management practices.	Spot herbicide use; mechanical harvest for fisheries enhancement; use deep cuts where possible; small scale cutting and dragging for individual shorelines.	Map weevil distribution, improve shoreline vegetation in critical areas to help weevils overwinter.

Evaluation: Map EWM and other plants; monitor lake sediments and water quality

Analysis: **Is program meeting Eurasian watermilfoil management goal?**

- Yes → **Continue program**
- No → **Adjust strategies or projects**

Sustaining the Program: **Continue program** / **Adjust strategies or projects**

Costs

- Lake soil testing (40 samples & interpretation) $4,000

In-kind: Volunteer: $500/yr X 3 yrs = $1,500

10. Increase native aquatic plants

Healthy coverage of native aquatic plants in a moderately fertile lake basin like Comfort Lake can help reduce nuisance algae blooms and sustain clear water conditions. In addition, native aquatic plant beds aid in maintaining a desirable fish community.

Coverage of native plants in Comfort Lake in 1998 was estimated at about 44 acres or roughly 20% of the lake bottom. Native plants grow out to about 14 feet of water depth. The goal for Comfort Lake is a bottom coverage of at least 40%.

At the present time, the native coverage is adequate, but algae blooms still occur. It is expected if the exotic plant curlyleaf pondweed could be controlled, along with other watershed and shoreland projects, nuisance algae blooms could be reduced. Curlyleaf pondweed control can be conducted through pre-emptive cutting.

Costs

• Exclosures	$10,000
• Transplanting aquatic plants if needed	$5,000
	$15,000

In-kind: local $300 + $300 + $400 = $1,000
DNR plant survey: $2,000

Native Aquatic Plant Management Program Summary

Goal: **Maintain native plant coverage to at least 40% of the lake bottom area.**

Strategy:

1. Clear up water to get deeper plant colonization.
2. Control exotic plants.
3. Minimize herbicide use, employ shoreland practices for native enhancement.

Action:

- Implement watershed and lake projects to reduce algae blooms. *Watershed District and Lake Association are the leaders.*
- Implement management programs for curlyleaf pondweed and, if needed, Eurasian watermilfoil. *Lake Association is lead. Watershed District assists.*
- Make available information on benefits of native plants ; make available small-scale plant management ideas for lake residents. *Lake Association and individuals share lead.*

Evaluation:

Use aquatic plant surveys to determine aquatic plant coverage.

Analysis:

Is program meeting native plant management goal?

Yes | No

Sustaining the Program:

Yes → **Continue program**

No → **Adjust strategies or projects**

11. Maintenance around culverts

Routine maintenance to remove sand and silt accumulation around culverts should allow for efficient flow between Little Comfort and Big Comfort. Other inflow areas should maintained as well. These include the Little Comfort inlet and the inlet at Big Comfort. Sometimes maintenance includes brush removal or downed tree removal.

Costs

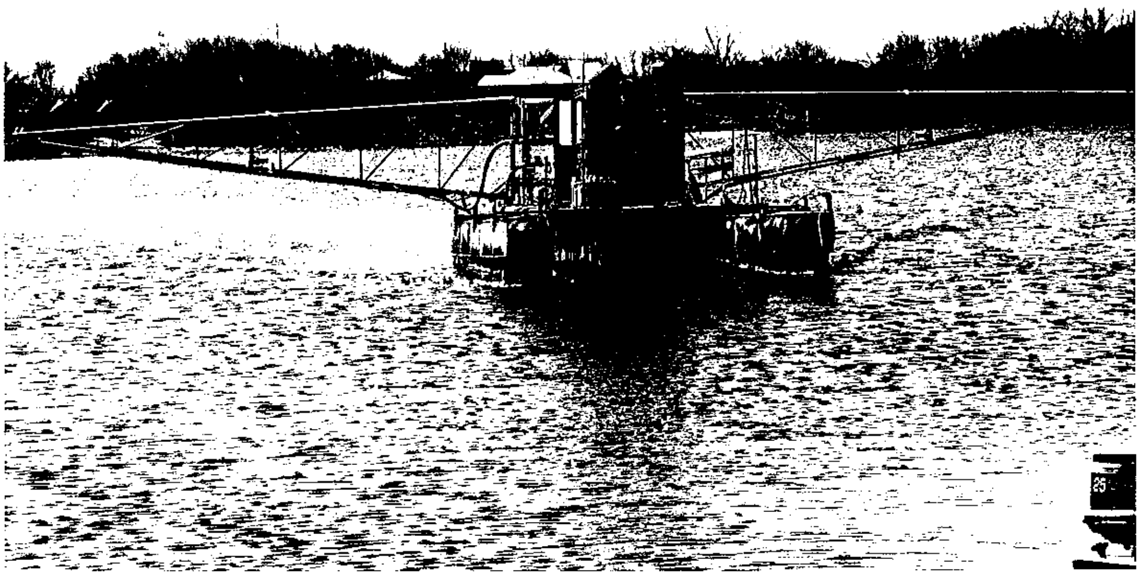
2 days @ $1,200 = $2,400

12. Whole lake alum treatment

An alum application is recommended as a reserve project, meaning it could be used only if needed. It is listed as a Phase II project, but would not be conducted until the second part of a Phase II which would occur in year 4, 5, or 6 of a Phase II project. In the meantime, watershed, shoreland, and lake projects are expected to produce the water quality goals for Big and Little Comfort Lake.

Costs

165 ac @ $550/ac = $91,000



Liquid alum is applied from a barge. It rests on top of the lake sediments and adsorbs phosphorus that is released from lake sediments. Thus prevents phosphorus that is released from lake sediments from getting up into the water column.

III.4B. Pollution control effectiveness analysis

A project list has been proposed to improve lake conditions. It is difficult to quantify specific pollution control effectiveness, so it will be described qualitatively (Table 36).

Table 36. Pollution control effectiveness.

Project	Description
Watershed Projects	
1. Implement stormwater BMPs in Subwatersheds 1 & 2.	Good for long term water quality protection.
2. Promote small-scale infiltration and rate controls in all subwatersheds.	Potential for some phosphorus reduction.
3. Lower culverts in Subwatershed 5.	Potential for some phosphorus reduction.
4. Install linear ditch aeration system in Subwatershed 5.	Potential for high level of phosphorus inactivation but is untested at this time.
Shoreland Projects	
5. Shoreland restoration	Helps improve wildlife habitat.
6. Maintain onsite systems	Good for environmental health protection as well as water quality protection.
Lake Projects	
7. Remove roughfish	Should allow aquatic plants to come back.
8. Install carp barriers	Aids long term carp control.
9. Plan for milfoil invasion	Should have a plan to control nuisance growth.
10. Increase native aquatic plants	Native plants are good for fish and water quality.
11. Maintenance around culverts	Could help reduce shoreline damage from high water.
12. Whole lake alum treatment	Proven technique for controlling p-release form sediments. May not be necessary if other projects are effective.

III.5. Implementation Monitoring and Evaluation

III.5A. Phase II monitoring plan and evaluation

One of the best tests for evaluating Comfort Lake improvements may be simply using the secchi disc readings to see if water clarity improves. However, other sampling will be conducted as well. The extent of curlyleaf pondweed growth will be monitored with pre-project monitoring and test plots beginning in the first year. Watershed runoff will continue to be checked to see if and how nutrients are being reduced especially in Watershed 5, the big watershed on the southeast side of the Big Comfort. Some of the watershed sampling will be conducted in conjunction with evaluating specific projects. Projects that have specific monitoring needs are shown in Table 37. Because several of these projects are new, specific data collection is necessary.

Table 37. Projects with monitoring needs. Costs are for sampling prior to implementation and then post-implementation. Costs include analysis for labor and collecting samples.

Alternative	Yes	No
1. Implement stormwater BMPs in Subwatersheds 1 & 2.	X	
2. Promote small-scale infiltration and rate controls in all subwatersheds.	X	
3. Lower culverts in Subwatershed 5.		X
4. Install linear ditch aeration system in Subwatershed 5.	X	
5. Shoreland restoration		X
6. Maintain onsite systems		X
7. Remove roughfish		X
8. Install carp barriers		X
9. Plan for milfoil invasion	X	
10. Increase native aquatic plants	X	
11. Maintenance around culverts		X
12. Whole lake alum treatment (reserve project)	X	

3. Monitoring

- Two automatic stations @ $5,000/yr x 3 yrs $30,000
- Big and Little Comfort Lake: $5,000 x 3 $15,000

In-kind: volunteers: $1,000/yr = $3,000
DNR: lake levels, etc, $1,000 x 3 = $3,000

4. Project Management

- Project meeting/administration/coord
  quarterly mtg @ $400 = $1,600/yr x 3 = $4,800
- Budget monitoring
  5 hrs/month = 60 hr/yr x 3 = 180 hr @ $80 = $14,400
  $19,200
- Reports
  $3,000/yr x 2 yr = $6,000
  Final report: $15,000
  $21,000
- Expenses: printing, mailing, office equipment
  $1,000/yr x 3 yr= $3,000
  =====
  $43,200

In-kind: Project meetings:
Task force: 2/yr x 3 yr = 6 meeting @ $1,000/meeting
Expenses & Misc.:
$2,000/yr x 3 yr (mailing, conferences, etc) = $6,000

COSTS: The cost for evaluating proposed projects over a 3-year period while in the Phase II implementation phase is $51,000.

Automatic stream monitoring stations at two sites for three years are recommended in order to determine if streams and the lake are improving. Low level monitoring includes eight storm events for two main tributaries and two base flow samplings per year ($12,000/yr for 3 years for a total of $36,000).

Comfort Lake would be sampled in May, June, July, August, and September at one station and two depths. Parameters in the epilimnion that would be analyzed include: TP and Chl A. Parameters in the hypolimnion include TP. The cost for routine sampling over three years is $5,000/yr for a total of $15,000.

Total cost for project evaluations and for routine sampling of Comfort Lakes is $51,000.

III.6. Roles and Responsibilities of Project Participants

The new Comfort Lake/Forest Lake Watershed District would serve as the Project Representative for establishing roles and responsibilities in the Phase II Implementation program. The Watershed District would take on most of the day-to-day administrative details.

Over the course of three years, the project team will probably change, but the main role players will come from the Watershed District (WD), Lake Associations, NRCS, SWCD, MPCA, DNR and Consultants.

The roles and responsibilities of project participants are summarized in Table 38.

Table 38. Milestone schedule for the implementation plan. The schedule is based on a 3-year (36 month) schedule.

Activity	Responsible Group
1. IMPLEMENTATION PROJECTS	
1. Implement stormwater BMPs in Subwatersheds 1 & 2.	WD, County
2. Promote small-scale infiltration and rate controls in all subwatersheds.	WD, Cities
3. Lower culverts in Subwatershed 5.	County, WD
4. Install linear ditch aeration system in Subwatershed 5.	Consultant/Contractor
5. Shoreland restoration	Lake Association, WD, MnDNR
6. Maintain onsite systems	Lake Association
7. Remove roughfish	Contractor, WD
8. Install carp barriers	WD, MnDNR
9. Plan for milfoil invasion	WD, MnDNR
10. Increase native aquatic plants	Lake Association
11. Maintenance around culverts	County
12. Whole lake alum treatment	WD
2. INFORMATION & EDUCATION	WD, County, SWCD, etc.
3. MONITORING PROGRAM	WD, Lake Association
4. PROGRAM MANAGEMENT	WD, County
FINAL REPORT	WD

III.7. BMP Operation and Maintenance Plan

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 39.

Projects were costed-out based on a 10-year period. Project O & M costs were included if costs were necessary within a 10-year period.

Table 39. Projects with operation and maintenance needs

	Operation & Maintenance Required in Phase 2	
	No	Yes
1. Implement stormwater BMPs in Subwatersheds 1 & 2.		X
2. Promote small-scale infiltration and rate controls in all subwatersheds.		X
3. Lower culverts in Subwatershed 5.		X
4. Install linear ditch aeration system in Subwatershed 5.		X
5. Shoreland restoration		X
6. Maintain onsite systems		X
7. Remove roughfish	X	
8. Install carp barriers		X
9. Plan for milfoil invasion	X	
10. Increase native aquatic plants	X	
11. Maintenance around culverts		X
12. Whole lake alum treatment	X	

III.8. Information and Education Program

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

Information should be distributed to home owners around Comfort Lake to lessen and prevent pollution of the lake from yard chemicals (pesticides and fertilizers) and cultural activities near the lake.

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

☻ Educate watershed residents regarding nonpoint pollution sources to the lakes and streams and in the Comfort Lake watershed.

☻ Increase the awareness and understanding of Comfort Lake 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 Comfort Lake 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 Comfort Lake.

To achieve the goals of the Lake Management Plan, a number of activities are planned and they are summarized below.

I. Newsletter: The Comfort Lake newsletter should do the following:

☻ Communicate basic information on the Comfort Lake Water Quality Improvement Projects.

☻ Give updates on important components of the project including dates of upcoming events.

☻ Foster the watershed concept and create an appreciation of Comfort Lake as a natural resource and natural treasure in order to encourage watershed landowner initiatives and participation.

- Create an awareness that everyone is responsible for conserving the soil and water resources and increase an understanding of the connection between land use activities and nonpoint source pollution.

- Inform watershed residents of available financial assistance including cost-sharing.

- Provide information on individual participation and progress of implementation practices and measures.

II. Fact Sheets: To disseminate basic information about a project, fact sheets may be created to meet the particular needs of watershed landowners.

- A "Shoreland Owners Guide" emphasizing lakeshore housekeeping practices, "Do's and Don'ts" to minimize nonpoint source pollution and improve lake water quality.

- Aquascaping and Landscaping for Wildlife instructions geared for homeowners.

III. Media: A program to involve the media in covering project events can begin with a meeting with local newspapers to acquaint editors and reporters with Comfort Lake.

News releases should be sent to local newspapers to announce project events such as tours, public information meetings, and demonstration project installations.

Also, newspaper feature articles can be sought to provide the general public with in-depth coverage on the progress of the project.

IV. Meetings: Several meetings to inform watershed residents, local government officials, and the general public should be scheduled. The purpose of these meetings will be to give updates on the progress of the project, to encourage more participation, and to inform the media and the public about implemented practices and water quality improvements. These meetings give project participants an opportunity to get input and feedback.

- Comfort Lake Association Annual Meeting. A yearly update of the project will be presented by the project participants.

☻ Public informational meetings to inform the local governmental officials and the general public would be held on a periodic basis.

☻ Information on the project would be presented at other local and regional water quality meetings to share ideas and to get feedback.

COSTS: The estimated cost for the Information and Education Program is $17,900. This is based on a THREE-year program. The cost breakdown is shown below.

Information and Education Program budget

	State/ Federal (In-Kind)	Local (In-Kind)	MPCA (Grant)	Total
Newsletter (1 per year, plus an extra if needed)	$800	$3,100	$5,100	$9,000
Fact sheet (prepare 6-8 fact sheets, mail with newsletter)	$400	$800	$1,300	$2,500
Media (newsletter articles 4 minimum)	$400	$600	$200	$1,200
Subtotal	$1,600	$4,500	$6,600	$12,700
Meetings				
Annual meetings (4)	$1,000	$1,500	$1,400	$3,900
Special meetings (2)	$200	$500	$600	$1,300
Total	$2,800	$6,500	$8,600	$17,900

III.9. Permits Required for Completion of Project

For the implementation plan to accomplish its objectives several conditions must be met and these include:

- Lead organization is the new Comfort Lake/Forest Lake Watershed District.
- Watershed District Board of Commissioners must accept the Implementation Plan
- Permits will be required for projects 3, 4, 11, and 12.
- MnDNR permits will be needed for projects 3, 4, 11, and 12.

III.10. Identification and Summary of Program Elements

The Comfort Lake Implementation Plan is designed to improve water quality in Comfort Lake so it can be brought into inline with ecoregion averages. To reach this goal, 12 projects and an information and education program have been proposed. 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 $373,400. The cost summary is shown at the end of this section.

The Comfort Lake 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.

The program elements are summarized at the end of this section in the Implementation Plan budget. The timeline associated with program elements is listed in the Milestone Schedule.

Summary of Proposed Watershed, Shoreland, and Lake projects for Comfort Lake

Projects	How They Benefit Water Quality
Watershed Projects	
1. Implement stormwater BMPs for commercial development in Subwatersheds 1 and 2.	With residential and commercial development ongoing in these 2 critical subwatersheds it is important that stormwater runoff water quality projects continue to be implemented.
2. Implement, where feasible, infiltration and runoff rate controls in all subwatersheds.	Reducing the volume of runoff even 10% through small-scale infiltration efforts could reduce flooding in Subwatershed 5 and reduce phosphorus release from saturated wetland sediments.
3. Lower culverts in Sunrise River in Subwatershed 5.	Two culverts apparently are set too high in Subwatershed 5. They may be acting like a dam. Lowering culverts may reduce water back-up and therefore reduce flooding or wetness in the Shallow Pond wetland complex.
4. Install linear ditch aeration in Subwatershed 5 (pending results of other linear ditch systems).	Aerating slow moving ditch water high in phosphorus and iron may precipitate iron which in turn would serve to scavenge dissolved phosphorus and make it biologically unavailable.
Shoreland Projects	
5. Promote shoreland restoration emphasizing native plant conditions.	Native landscaping and lakescaping improve runoff water quality and help attract wildlife. Buffer strips and shoreland vegetation reduce nutrient loading to the Comfort Lakes.
6. Maintain onsite systems.	Septic systems are mostly in good working order. Maintenance and ongoing education should help to keep them from being either an environmental health problem or a water quality problem.
Lake Projects	
7. Remove roughfish through the use of carp traps and commercial fishing.	Use commercial fishermen to fish down the carp population in both Comfort Lakes. Carp may be limiting aquatic plant growth in Big Comfort Lake. Reducing carp may improve plant coverage.
8. Install carp barriers to reduce carp movement into Judicial Ditch 1 (Sunrise River).	If carp can be fished down to lower numbers, carp barriers could inhibit movement into the Sunrise River for spawning, helping to keep carp recruitment down in the Comfort Lakes.
9. Conduct lake soil testing to set-up contingency plan for Eurasian watermilfoil invasion.	Milfoil has not been found at the present time. Lake soil testing will delineate areas that could produce nuisance growth. Lake mapping will then help determine a management approach and level of effort needed to control nuisance growth.
10. Develop program to promote native plants and reduce spraying. Transplant macrophytes if they don't come back after fish removal.	Native plants need to cover more area then they presently do to sustain good water quality.
11. Maintenance dredging around culverts, especially off Highway 8.	Maintenance dredging around culverts at Highway 8 will help maintain water flow from Little to Big Comfort. Other culverts need maintenance also.
12. Whole lake alum project (reserve project to be implemented if needed)	An alum application in both Little and Big Comfort Lakes would reduce phosphorus loading from lake sediments. This is a reserve project meaning it may not be needed if other management projects achieve water quality improvements. It would be scheduled for Year 4 or 5, putting it in Part 2 of a Phase II program.
Education Program	
• Promote pollution prevention by landowners on a watershed basis. This would target nutrient source reduction and be done through information and education programs.	Landowners in the direct drainage area have control of what runs off their property into the lake. Fertilizer use and landscaping are areas of active involvement. I&E programs will give a full range of options for pollution prevention techniques that keep nutrients form entering lakes and wetlands in the watershed.
• Community Education program which includes public access rules for Little Comfort Lake, fish limits for lakes, snowmobile trails, etc.	Framework should be established for transmitting shoreland rules, public access rules, snowmobile regulations, and even fishing limit laws to residents and the general public with a mechanism for enforcement.
• Coordinate efforts of local and state agencies to enforce shoreline and lake rules and regulations	Shoreland rules are emerging at the state and county levels. Shoreland includes the upland fringe, the shoreline, and shallow water. Rules need to be well publicized with a mechanism for enforcement.
Ongoing Programs	
• Establish Ordinary High Water Level elevations for Big and Little Comfort Lakes and a maintenance program.	The MnDNR will install a fixed crest weir at the outlet of Big Comfort in 2000. This will help maintain lake levels at the mean water level.
• Implementation of surface water management plan in Wyoming Township.	Stormwater management practices should continue to be implemented with new development.
• Intergrated water management policies through the Watershed District.	The Comfort Lake/Forest Lake Watershed District should be able to establish watershed wide policies that are consistent with good lake improvement goals.

III.11. Milestone Schedule

The Comfort Lake implementation project is scheduled for a 3-year time period. The milestone schedule is shown in Table 40. Some projects have different starting times, and some projects are dependent on the success of earlier projects. For example, an alum application would not occur until the fourth year after evaluating the effectiveness of curlyleaf pondweed removal and after the mid-project review.

Table 40. Milestone schedule for the implementation plan. The schedule is based on a 3-year (36 month) schedule.

Activity	Time Frame (1-36 months)	Responsible Group
KICK OFF MEETING	1	Task force
PROJECT SAMPLING	6-30	WD, Volunteers
1. Implement stormwater BMPs in Subwatersheds 1 & 2.	2-30	WD, County
2. Promote small-scale infiltration and rate controls in all subwatersheds.	2-24	WD, Cities
3. Lower culverts in Subwatershed 5.	12-18	County, WD
4. Install linear ditch aeration system in Subwatershed 5.	12-30	Consultant, Contractor
5. Shoreland restoration	6-30	Lake Association, WD, MnDNR
6. Maintain onsite systems	6-36	Lake Association
7. Remove roughfish	12, 24	Contractor, WD
8. Install carp barriers	12-14	WD, MnDNR
9. Plan for milfoil invasion	6-18	WD, MnDNR
10. Increase native aquatic plants	6-24	Lake Association
11. Maintenance around culverts	8	County
12. Whole lake alum treatment	60	WD
MID PROJECT REVIEW	18	Task Force, MPCA
INFORMATION & EDUCATION	6-36	Task Force
PROGRAM MANAGEMENT	6-36	WD, MPCA
FINAL REPORT	30-36	WD

III.12. Implementation Project Budget

The estimated cost for the Comfort Lake Implementation Project is $516,700. The cost represents in-kind services, cash to be supplied through an MPCA grant, services from the Comfort Lake/Forest Lake Watershed District. A summary of costs for the Implementation Plan is shown in Table 41.

Table 41. Implementation plan budget.

Program Element	Cost	State/ Federal (In Kind)	Local (In Kind)	MPCA (Grant) or Watershed District (cash)
1. Implementation Projects				
1. BMPs in Subwatersheds 1 & 2	90,000	--	45,000	45,000
2. Infiltration and rate controls	100,000	--	50,000	50,000
3. Lower culverts in Subwatershed 5	7,000	--	--	7,000
4. Install aeration system in Ditch 1	20,000	--	--	20,000
5. Shoreland restoration	27,000	3,000	9,000	15,000
6. Maintain onsite systems	8,200	--	3,000	5,200
7. Remove roughfish	9,000	--	--	9,000
8. Install carp barriers	1,200	--	--	1,200
9. Plan for milfoil invasion	5,500	--	1,500	4,000
10. Increase native aquatic plants	18,000	2,000	1,000	15,000
11. Maintenance around culverts	3,900	--	1,500	2,400
12. Whole lake alum treatment (reserve)	103,000	--	--	103,000*
Subtotal Element 1	**392,800**	**5,000**	**111,000**	**276,800**
2. Information and Education Program				
Newsletters, fact sheet	12,700	1,600	4,500	6,600
Informational meetings	5,200	1,200	2,000	2,000
Subtotal Element 2	**17,900**	**2,800**	**6,500**	**8,600**
3. Monitoring				
Routine lake and watershed	**51,000**	**3,000**	**3,000**	**45,000**
4. Project Management				
Project meetings/administration	25,000	2,000	4,000	19,000
Reports	21,000	--	--	21,000
Expenses & Misc	9,000	2,000	4,000	3,000
Subtotal Element 4	**55,000**	**4,000**	**8,000**	**43,000**
TOTALS	**516,700**	**14,800**	**128,500**	**373,400**

* Alum treatment is a reserve project that may not be needed if lakes improves.

III.13. Conclusions

The implementation plan has several project areas to improve water quality conditions in Comfort Lake.

- Watershed projects
- Shoreland projects
- Lake projects
- Information and education program
- On-going projects

A 3-year implementation timeline is proposed. Although the cost for the whole program is substantial, costs are distributed over a wide number of participants over three years. For example, the stormwater water quality management approach needs to be designed by engineers, but the cost of installation of projects will more than likely be picked up by developers. Likewise the infiltration approach needs to be evaluated first, with later installations financed by developers.

The alum project is expensive and might not be necessary if lake water quality improves. Alum is a reserve project.

Lastly, the timing of the formation Comfort Lake/Forest Lake Watershed District is helpful for leading the way into the implementation phase.

III.14. References

Brabrand, A., B.A. Faafeng, and J.P.M. Nilssen. 1990. Relative importance of phosphorus supply to phytoplankton production: fish excretion versus external loading. Canadian Journal of Fisheries and Aquatic Sciences 47:364-372.

Carignan, R. and J. Kalff. 1980. Phosphorus sources for aquatic weeds: water or sediments? Science 207: 987-989.

Lamarra, Jr., V.A. 1975. Digestive activities of carp as a major contributor to the nutrient loading of lakes. Verh. Internat. Verein. Limnol. 19: 2461-2468.

Lindholm, G.F., D.F. Farrell, and J.O. Helgesen. 1974. Water resources of the Crow River Watershed, South-central Minnesota. Department of the Interior United States Geological Survey. Hydrologic Investigations Atlas HA-528 (sheet 1 of 3).

Nakashima, B.S. and W.C. Leggett. 1980. The role of fishes in the regulation of phosphorus availability in lakes. Canadian Journal Fisheries Aquatic Sciences 37: 1540-1549.

Nurnberg, G.K. and P.J. Dillon. 1993. Iron budgets in temperate lakes. Can. J. Fish. Aquat. Sci. 50:1728-1737.

Reddy, K.R. 1991. Phosphorus sorption capacity of stream sediments and adjacent wetlands. Preprint, American Chemical Society, Atlanta, GA Conference.

Richardson, C.J. 1985. Mechanisms controlling retention capacity in freshwater wetlands. Science 228: 1424-1427.

Rogers, K.H. and C.M. Breen. 1982. Decomposition of Potamogeton Crispus 1. the effects of drying on the pattern of mass and nutrient loss. Aquatic Botany 12:1-12.

Sand-Jensen, K., C. Prahl, and H. Stokholm. 1982. Oxygen release from roots of submerged aquatic macrophytes. Oikos 38:349-354.

Sharpley, A.N. 1993. An innovative approach to estimate bioavialable phosphorus in agricultural runoff using iron oxide-impregnated paper. Journal of Environmental Quality 22:597-601.