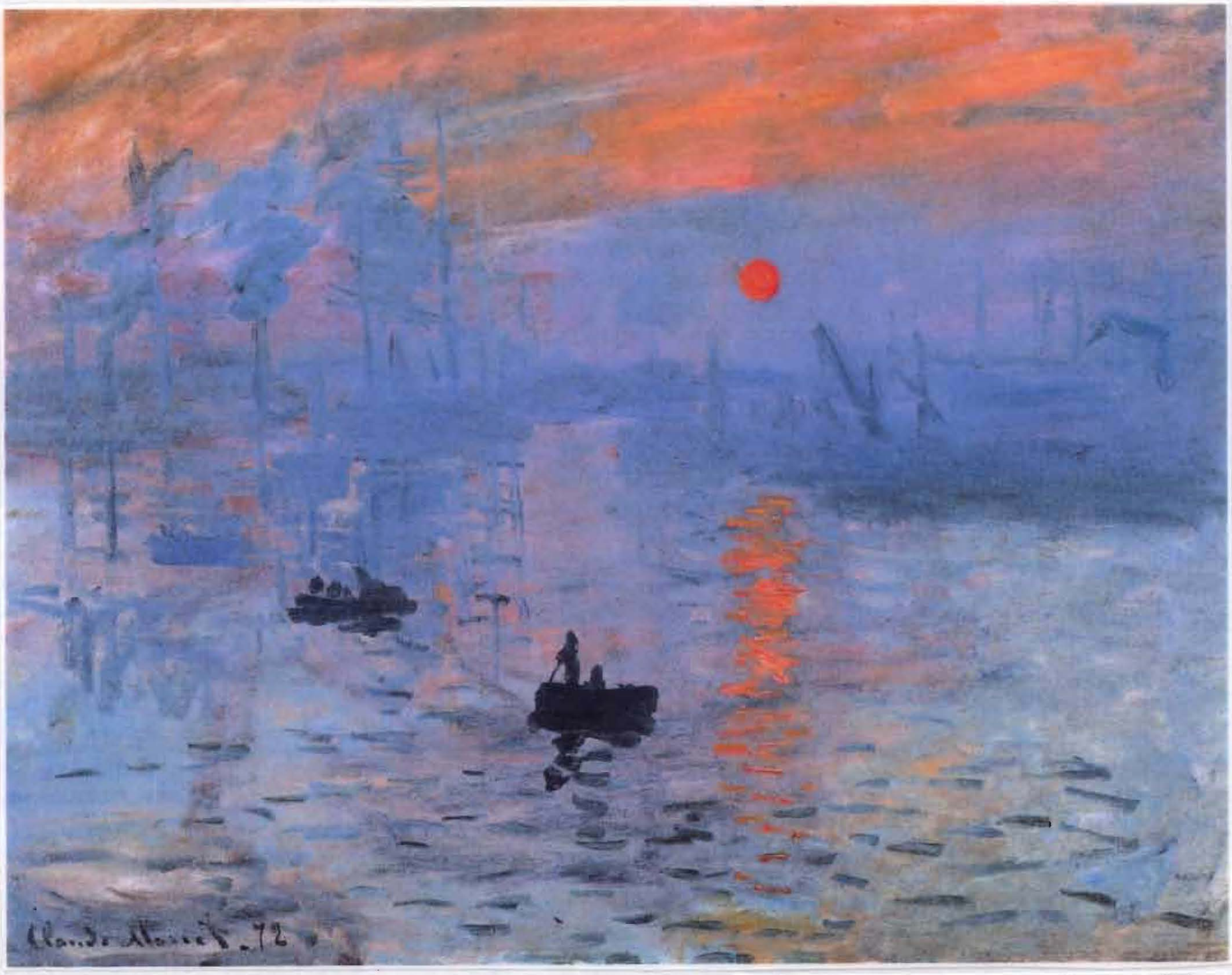


Claude Monet: *Impression, Sunrise*, 1872

Thunder Lake, Eagle Lake, and Island Lake Lakes and Watershed Characterization

June 1994

Submitted to:
Thunder Lake Club
Marinette County, Wisconsin

Prepared by:
Marinette County Land Conservation Department and
Blue Water Science
St. Paul, Minnesota

LPL-123

SUMMARY

The Thunder Chain of Lakes, Thunder, Eagle and Island Lakes, are located in Marinette County, Wisconsin.

Goals The goals of this project were:
- -to examine existing lake conditions
- -to develop a lake management plan that protects, maintains, and enhances the lakes water quality.

Watershed Characteristics

Thunder Lake
- -Thunder Lake is a drainage lake that drains 2,508 acres of land.
- -The watershed is dominated by forest (81%).

Eagle Lake
- -Eagle Lake is a glacial seepage lake.
- -Eagle Lakes watershed is 218 acres.
- -The watershed is dominated by forest (91%).

Island Lake
- -Island Lake is a glacial seepage lake.
- -Island Lakes watershed is 245 acres and is dominated by forest (98%).

Water Quality and Quantity Monitoring Methods
- -Sampling was conducted in May, June, July, and August 1992.
- -Chemical analysis was conducted by the Wisconsin Laboratory of Hygiene.

The following parameters were analyzed:

Chl a	Temperature
Dissolved Oxygen	Conductivity
Nitrate plus Nitrite	Total Kjeldahl Nitrogen
Total Phosphorus	Secchi Disc
Ammonia	Plant Survey
Underwater Video	

Dissolved Oxygen and Temperature
- -Thunder Lake is strongly stratified during the summer.
- -Eagle Lake weakly stratifies during the summer.
- -Island Lake remains well-mixed, and does not stratify.

--Contents--

Page Number

Summary 1

1. Introduction and Project Setting 4

2. List of Projects That Have Been Done on Thunder, Eagle, and Island Lake 5

3. Geologic Setting 6

4. History of Thunder Lake, Eagle Lake, and Island Lake Area 8

5. Watershed Characteristics 10
   Land use 10

6. Lake Characteristics 16
   Physical/Chemical Data: DO, Temperature, Secchi Disc 19
   Physical/Chemical Data: Phosphorus, Nitrogen, and Trophic State Index 27
   Macrophytes 30

7. Thunder, Eagle, and Island Lake Phosphorus Model 34

8. Lake Status 40

9. Lake Management Projects for Thunder, Eagle, and Island Lakes 43

Nutrients

-Thunder Lake has the lowest nutrient concentrations of the three lakes, followed by Eagle and then Island. All three exhibit favorable water quality.

Macrophyte Status

-Thunder Lake survey consisted of twenty transects. Rooted plants were found in water depths to 16 feet. Plant coverage is about 8% of the bottom of the lake.
-Eagle Lake a survey parallel to shore was conducted, few plants were found.
-Island Lake a survey using a canoe and an underwater video camera were used. Approximately 90% bottom coverage was observed.
-Thunder Lake has Eurasian watermilfoil. It is well established, but not widespread. It covers approximately 4 acres or 3%.

Lake Water Quality Trends

-Water chemistry results are comparable to Ecoregion values
-No serious degradation noted at this time
-The data base does not go back far enough to examine trends, however the lakes are in good shape at this time in regard to phosphorus concentrations and transparency.

Lake Modeling

-The Canfield and Bachmann Phosphorus Model (1981) was used.
-For Thunder Lake, the model predicted a concentration of 11 ppb of phosphorus, and the actual lake phosphorus level was 9 ppb.
-For Eagle Lake, the model predicted 17 ppb of phosphorus, and the actual lake phosphorus level was 10 ppb.
-For Island Lake, the model predicted 16 ppb of phosphorus, and the actual lake phosphorus level was 20 ppb.

How Close Are Lakes to the Danger Zone?

The Trophic State Index (TSI) rates a lake from 1 to 100, with low numbers being the best. Thunder Lake is currently rated as an oligotrophic-mesotrophic lake. Thunder Lake could reach the status of eutrophic lake if an additional 475 kilograms of phosphorus were added to the lake on an annual basis. Eagle Lake and Island Lake are currently rated as mesotrophic lakes. The threshold level of phosphorus input that could cause eutrophic conditions is an additional 35 kilograms for Eagle Lake, and 21 kilograms for Island Lake (on an annual basis). The current average TSI for Thunder is 39, for Eagle is 40, and for Island is 49 (TSI ratings are based on the chlorophyll a level, total phosphorus concentrations, and secchi disk transparency).

Recommended Lake Management Projects

<u>County-level</u>
1. Adopt an ordinance for erosion control at Construction sites.
2. Adopt an ordinance for maintaining and upgrading septic tanks.

<u>Local level (shoreland)</u>

3. Aquascaping/native plant reestablishment.
4. Eurasian watermilfoil control.
5. Landscaping for wildlife.
6. On-site system maintenance program.
7. Lake resident projects.
8. Continue a lake monitoring program.

Conclusions

All three lakes have phosphorus concentrations and transparencies within ecoregion values. Thunder and Eagle lakes ranks higher than Island Lake. Thunder Lake has Eurasian watermilfoil that grows to nuisance levels along several stretches of shoreline.

All three lakes are in a protection and maintenance mode, rather than a restoration mode. Thunder Lake can assimilate more phosphorus than Eagle or Island because of its larger volume. However, it is vulnerable to phosphorus loads from Thunder Creek. Watershed protection, should result in low loadings to Thunder Creek and thereby low phosphorus inputs to Thunder Lake is paramount. Shoreland best management practices are important for all three lakes, but especially Eagle and Island.

No major lake restoration projects are necessary in the near term. The need for alum addition for Thunder Lake is not eminent. However, it would be a good idea to start a lake fund to be used for special projects.

1. INTRODUCTION AND PROJECT SETTING

Thunder Lake is a drainage lake and Eagle and Island Lakes are glacial seepage lakes located in Marinette County, Wisconsin (Figure 1). Thunder Lake is an oligotrophic-mesotrophic lake with moderate phosphorus levels (4-20 ug/l) and an excellent secchi disc transparency of 17-18 feet in summer. Eagle Lake is a mesotrophic lake with moderate phosphorus levels (6-16 ug/l) and an outstanding secchi disc transparency (13-19 feet) in the summer. Island Lake is a mesotrophic lake with the highest phosphorus level of all three lakes (20-25 ug/l) and a good secchi disc transparency (7+ feet - disc was resting on the pond bottom) in the summer.

The goals of this project were to examine existing lake conditions and to develop lake management plans to protect, maintain, and enhance lake water quality for the short term and long term.

2. LIST OF PROJECTS THAT HAVE BEEN DONE ON THUNDER LAKE, EAGLE LAKE, AND ISLAND LAKE

Only a handful of projects have been conducted on Thunder, Eagle, and Island Lakes, not including fish surveys conducted by the Wisconsin Department of Natural Resources.

In 1991 Eurasian Watermilfoil was found and identified on Thunder Lake.

In 1992 a Lake Management Grant was applied for and accepted. Blue Water Science, St. Paul, MN was selected as the consulting firm for the grant.

In 1993 Thunder Lake had an aquatic plant screen that was placed at the public landing to try to control the spread of Eurasian Watermilfoil.

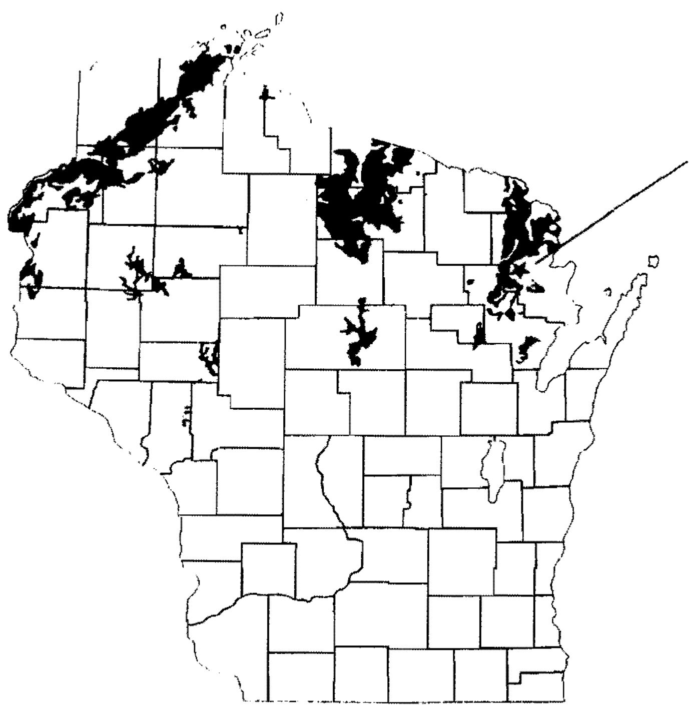


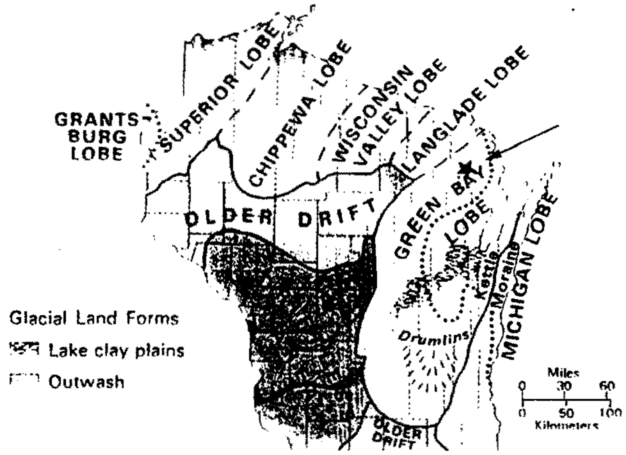
Figure 1. Location of Thunder, Eagle, and Island Lakes shown on a Wisconsin map. The approximate location of the lakes is shown by the black star. The black shading represents the distribution of northern sandy soils.

3. GEOLOGIC SETTING

It is important to know the context of the land that the lakes reside in, because it has ramifications for water quality.

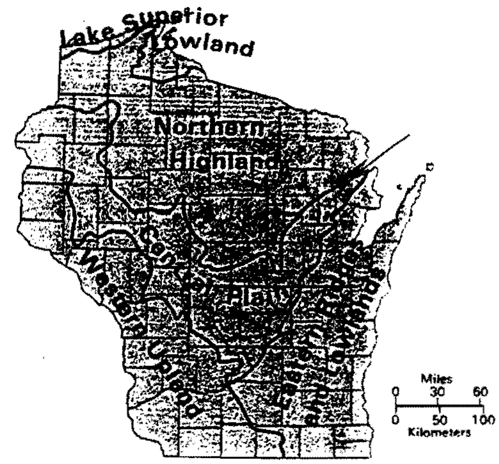
Thunder, Eagle, and Island Lakes were formed from a depression made by an ice block that was left behind when the glaciers retreated from this area about 16,000 years ago. Thunder, Eagle, and Island Lakes are located in the Green Bay Lobe of the last glaciation (Figure 2, Map 6) which is in the Central Plain geographic provence (Figure 2, Map 8). Thunder Lake drains to the Thunder River, then to the Peshtigo River which eventually flows into Green Bay, Lake Michigan. Thunder, Eagle, and Island Lakes are very close to the continental divide (Figure 2, Map 9). Most of the land area now is forested (Figure 2, Map 11).

From these maps, one can see that the lakes are in sandy outwash soils, in predominantly forested areas. For the Thunder Lake group, background soil fertility is low compared to more highly agricultural areas where soil fertility is typically high.



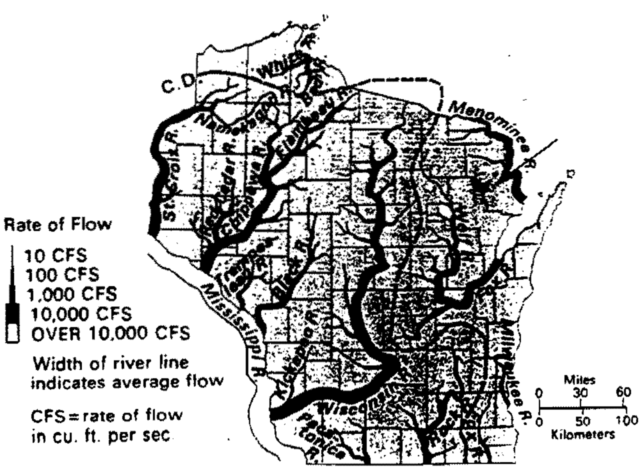
Map 6. GLACIAL GEOLOGY

The last major advance of the ice sheet over Wisconsin was about 16,000 years ago. It covered all but the "driftless" and "older drift" areas. A later ice advanced about 11,000 years ago (dotted boundaries), burying a forest in Manitowoc County. Many land forms were created by the glacial ice and meltwaters: Moraines (solid lines), elongated hills called drumlins, outwash, and lake clay plains. Many peat bogs and lakes occupy glacial pits called kettles.



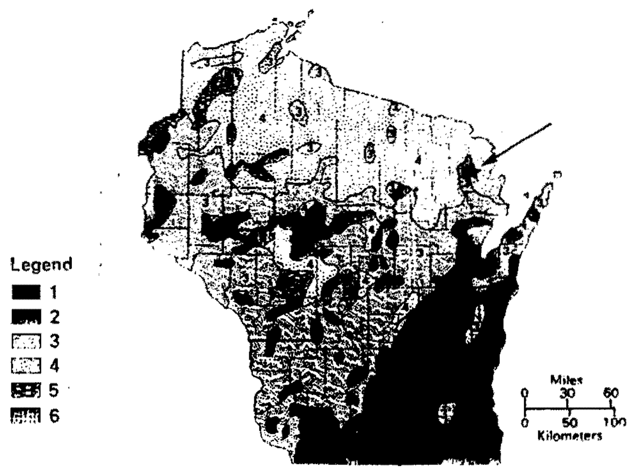
Map 8. GEOGRAPHIC PROVINCES (after Martin, 1932)

The Lake Superior Lowland is an old glacial lake bottom sitting in a much older depression in the bedrock surface. The Northern Highland is a glacial-drift-covered Precambrian "dome," a southern extension of the "Canadian Shield" of igneous and metamorphic rocks. The Central Plain is on an arc of Cambrian sandstones. The drift-covered Eastern Ridges and Lowlands are crossed by dolomite escarpments. The Western Upland is dissected by numerous tributaries to the Mississippi and Wisconsin Rivers.



Map 9. PRINCIPAL RIVERS AND THEIR AVERAGE FLOW

Thirty percent of the state drains to the St. Lawrence River basin, and the remaining 70 percent to the Mississippi River basin. The dashed line represents the continental divide (C.D.) between these two major basins. Peak flows are in March, April and June. The Wisconsin River drains 21 percent of the area of the state; the Chippewa-Flambeau system drains 17 percent; the Fox-Wolf system in northeastern Wisconsin drains 12 percent of the state.



Map 11. AGRICULTURAL AND FORESTRY LAND USE

The map shows land use in terms of proportions of land devoted to agriculture and forestry. Highly productive farm land (1), with less than 15 percent of woodland, is in southern counties. Productive farm land (2), with the same extent of woodland, is prominent in the east, but is also widely scattered. Agricultural land with 15 to 50 percent in woodland (3), occupies about half of the area of the state. Forest lands, not sandy (4), are prominent in the north. Jack pine (5), and scrub oak (6) sandy lands are concentrated in the central plain and northern counties.

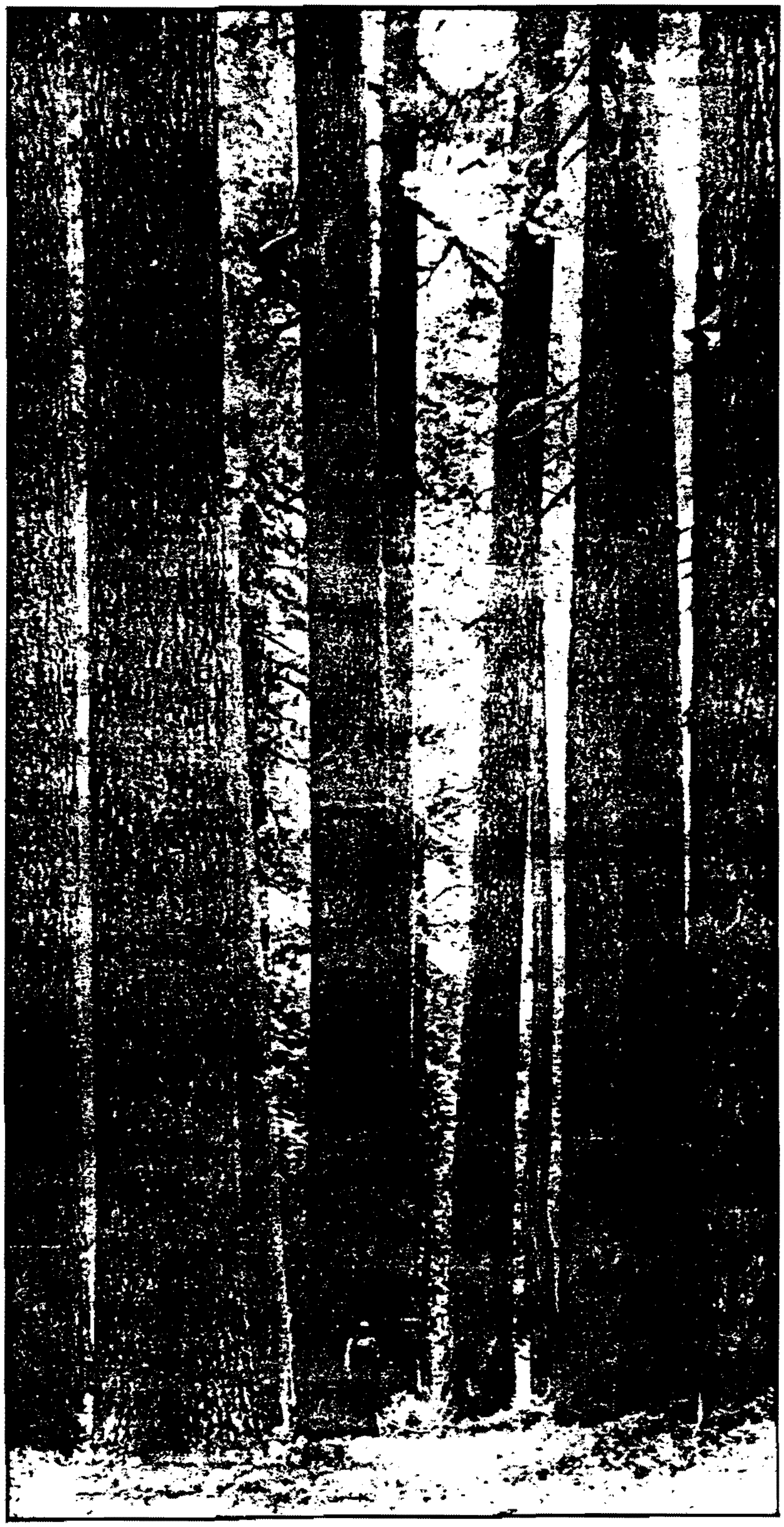
Figure 2. Glacial geology, geographic provinces, rivers and lake use in the Thunder, Eagle, and Island Lakes area. Source: F.D. Hole, 1977. Photo-mosaic soil map of Wisconsin. University of Wisconsin Extension-Madison. A2822-1.

4. HISTORY OF THUNDER LAKE, EAGLE LAKE, AND ISLAND LAKE AREA

Thunder, Eagle, and Island Lake are located in a region pock-marked with lakes. About one hundred years ago the area and the watershed of Thunder, Eagle, and Island Lakes were dominated by pine forests. Many of the original pines that the first loggers saw were well over 400 years old. Most of the pine forest was cut in the late 1800's (Figure 3). Today we are looking at second and third growth forest for the most part.

Land use changes can have major impacts on water quality. Specific land use changes in regard to converting forested acreage to agricultural have occurred, but we do not have the specific information.

For lake protection, it is important for current land owners to be aware of their impacts to lake water quality and to practice appropriate best management practices. Future development and land conversions should follow appropriate erosion control methods at construction sites and practice good landscaping techniques. More information on these approaches is given at the end of the report.



"The crowns of great white pine and Norways lifted themselves high above the ground and became intertwined to cast a shade like the dusk of a tunnel. Starved for sunlight, the branches below them had given up trying to live, and as the tree tops swayed in the wind, they jostled each other until they became loosened and fell to the ground, leaving the trunks tall straight and clear."--Isabel Ebert.

Figure 3. Example of what the virgin pine forests looked like prior to logging. (Source: Minocqua-Woodruff Centennial Edition, 1988)

5. WATERSHED CHARACTERISTICS

Land Use

General land use in the watershed is shown in Figure 4. The Thunder, Eagle, and Island Lake watersheds encompass approximately 2,971 acres. Of that 2,971 acres, forest lands dominate with 2,481 acres followed by 467 acres of wetlands area and then 23 acres of residential lands (Table 1). Residential land use is composed of about 23 acres of tier one cabins around Thunder Lake, that are predominately seasonal in nature with about 5 homes being permanent.

Table 1. Land use in the Thunder, Eagle, and Island Lake watersheds. Areas presented are in acres. Numbers shown in parentheses are the percent of land use.

Land use of each Lake

	Forest	**Wetlands***	**Urban**	**Total**
Thunder Lake	2,037 (81)	448 (18)	23 (1)	2508
Eagle Lake	199 (91)	19 (9)	0 (0)	218
Island Lake	245 (100)	0 (0)	0 (0)	245
	2,481 acres	467 acres	23 acres	2,971 acres

*areas shown do not include the lakes of Thunder, Eagle, and Island, but in the Thunder watershed the other lakes are included under the heading of wetlands.

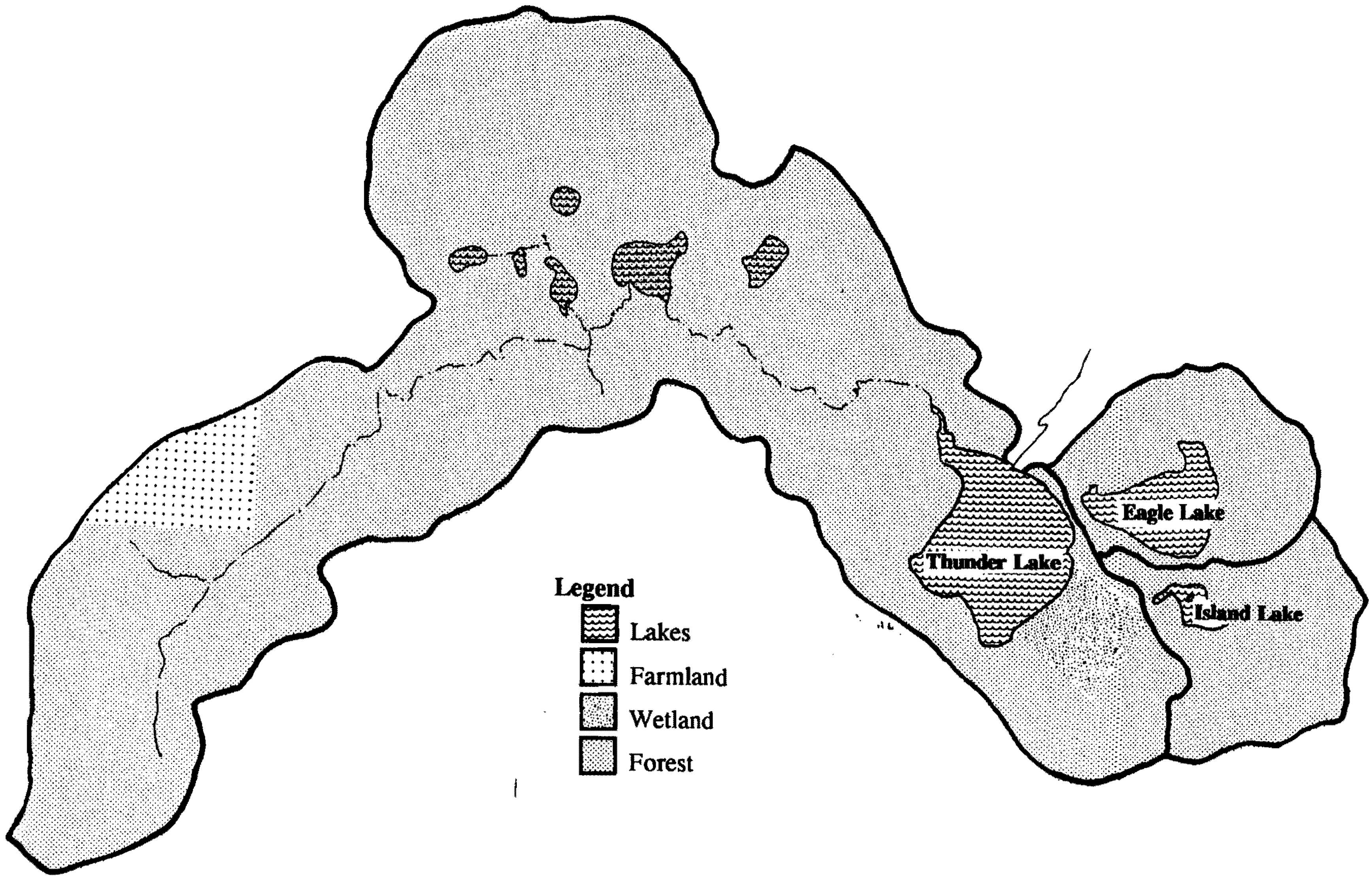


Figure 4. Watershed map of Thunder, Eagle, and Island Lakes.

Soils

Soils in the watershed are dominated by peaty and sandy soils (Figure 5 and Table 2). Some of the soils have limitations for septic tank/soil absorption systems and these soils are shown in Figure 6. Of the soils with limitations, the main problem is the soils are a poor filter, meaning septic tank effluent drains through the sand relatively quickly and thus there may not be adequate nutrient or bacterial removal. Information addressing problems with septic tank/soil absorption systems is found in the management section (last section).

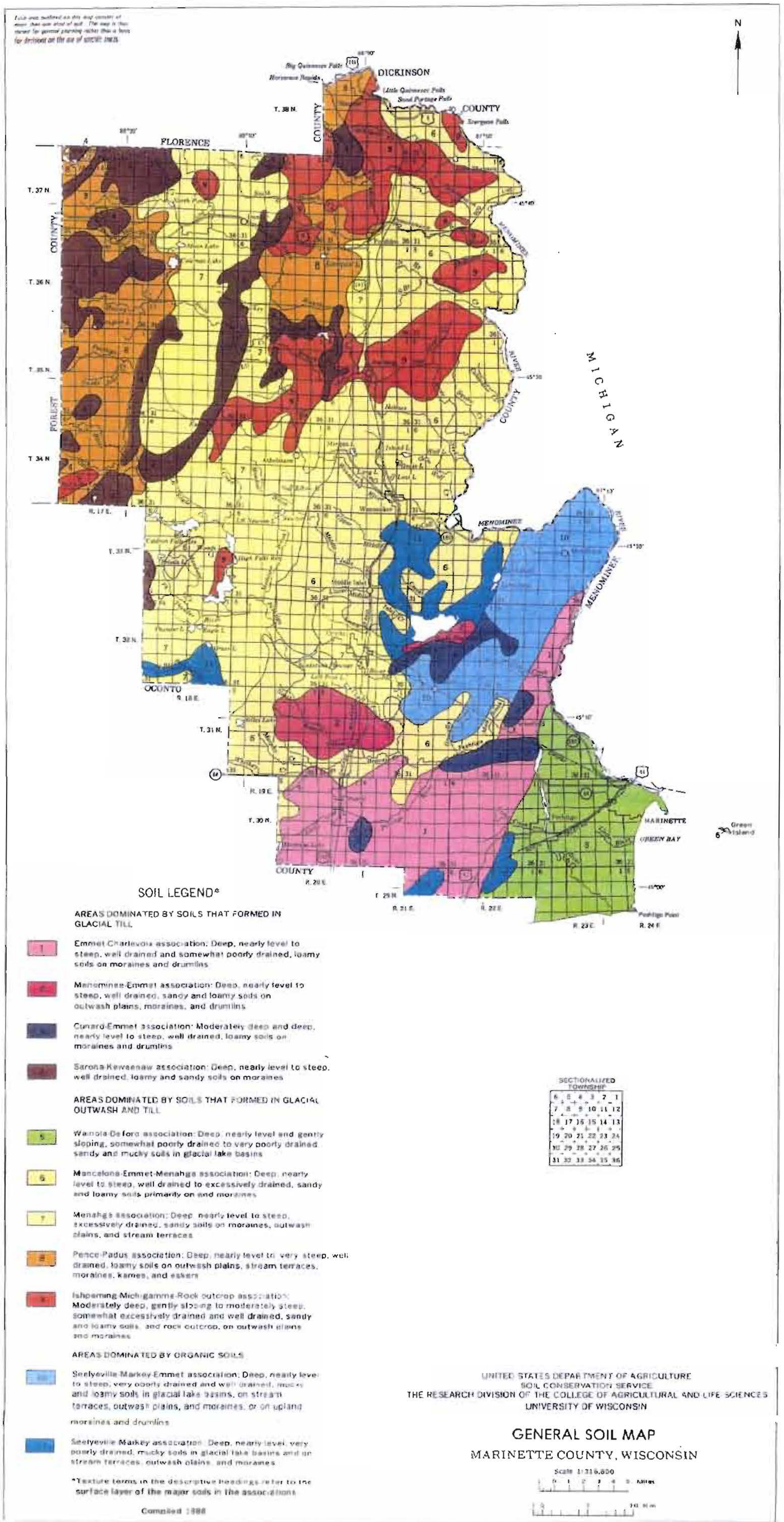


Figure 5. Soil map of area around Thunder, Eagle and Island Lakes.

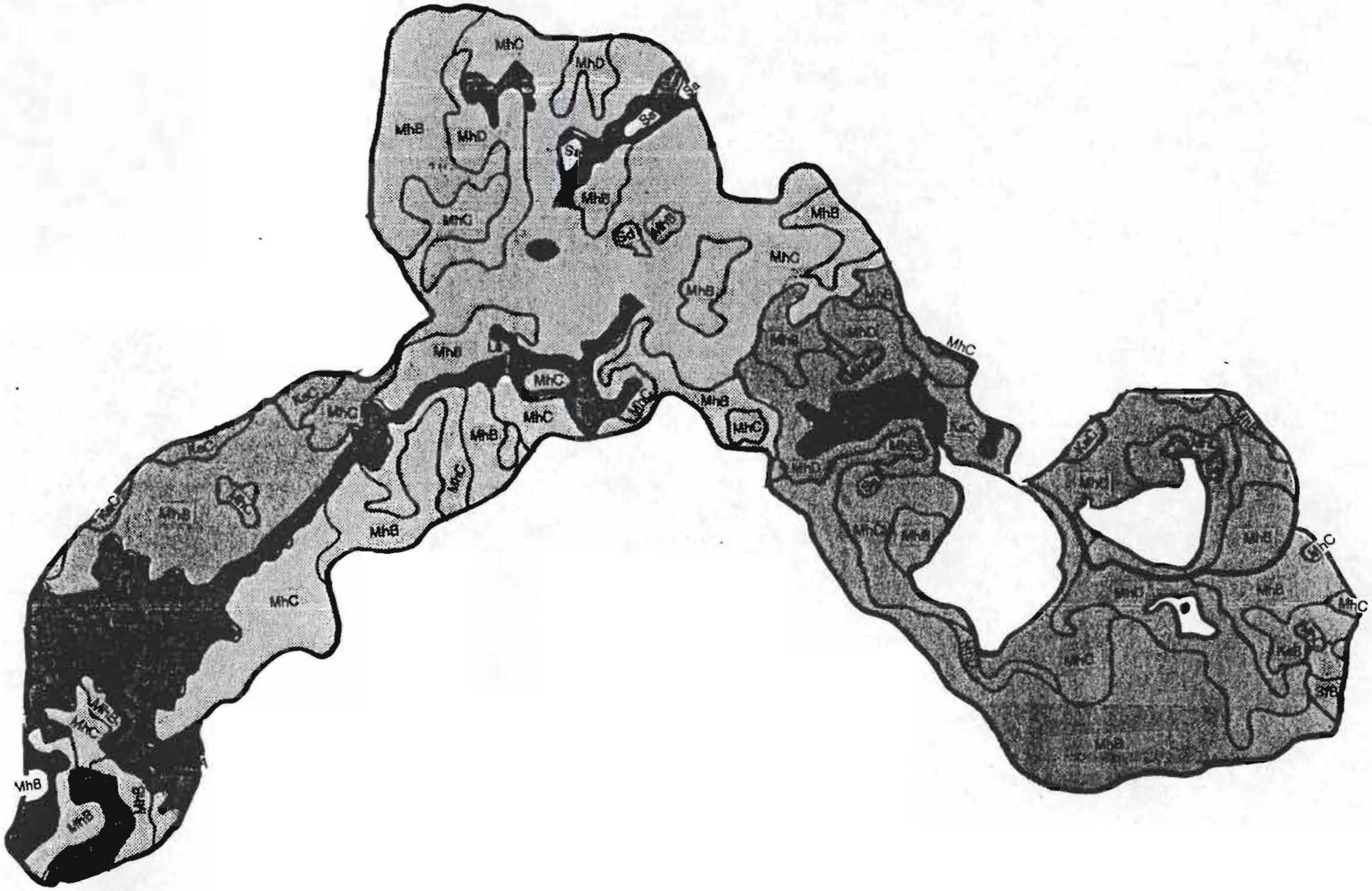


Figure 6. Soil series of the Thunder Lake watershed. Nearly all the soils in the watershed are rated *severe*, due to rapid infiltration and high groundwater.

Table 2. Soils legend for Thunder Lake watershed and septic tank limitations.

Symbol	Soil Name	Erosion Hazard	Septic System Absorption Field	Permeability (in/hour)	Depth to Water Table (ft)
Ar	Arnheim silt loam, 0 to 1 % slope	slight	severe: flooding, wetness	0.6-6	0-1
AuA	AuGres loamy sand, 0 to 3 % slope	slight	severe: wetness	6-20	0.5-1.5
CtB	Croswell loamy sand, 1 to 6 % slope	slight	severe: wetness, poor filter	6-20	2-4
IxC	Ishpeming-Rock outcrop complex, 4 to 15 % slopes	slight	severe thn layer, seepage	6-20	>6
KaB	Karlin loamy fine sand, 2 to 6 % slope	slight	severe: poor filter	2-20	>6
KaC	Karlin loamy fine sand, 6 to 15 % slope	slight	severe: poor filter	2-20	>6
Ls	Loxley & Dawson peats, 0 to 1 % slope		severe: subsides, ponding, percs slowly	0.2-20	+1.0
MhB	Menahga sand, 0 to 6 % slope	slight	severe: poor filter	6-20	>6
MhC	Menahga sand, 6 to 15 % slope	slight	severe: poor filter	6-20	>6
MhD	Menahga sand, 15 to 25 % slope	moderate	severe: poor filter, slope	6-20	>6
Na					
Rc	Roscommon mucky loamy sand, 0 to 2 % slope	slight	severe: ponding, poor filter	6-20	+1-1.0
Sa	Saprists & Psammaquents, ponded				
Sd	Seelyeville & Markey mucks, 0 to 1 % slope	slight	severe: ponding, subsides, poor filter	0.2-20	+2-2.0
SfB	Shawano loamy fine sand, 2 to 6 % slope	slight	severe: poor filter	6-20	>6

6. LAKE CHARACTERISTICS

Physical/Chemical Data Emphasizing Dissolved Oxygen, Temperature, and Secchi Disc

Thunder Lake

Thunder Lake is 135 acres in size, with a watershed of 2,509 acres. The average depth of Thunder Lake is 9.4 meters (31 feet) with a maximum depth of 18.9 meters (62 feet) (Table 2). A lake contour map is shown in Figure 7. Thunder Lake is located in an area of Wisconsin that is dominated by forests. The Thunder Lake watershed is 81% forest (2,037 acres), 18% wetlands (448 acres) and 1% urban (23 acres) (listed in Table 1 and shown again in Table 2).

The secchi disc transparency had an average summer depth of 5.3 meters (17.4 feet) in 1992.

The summer dissolved oxygen (DO) and temperature profiles are shown in Figure 8. A concern for Thunder Lake is the decrease in oxygen in the hypolimnion.

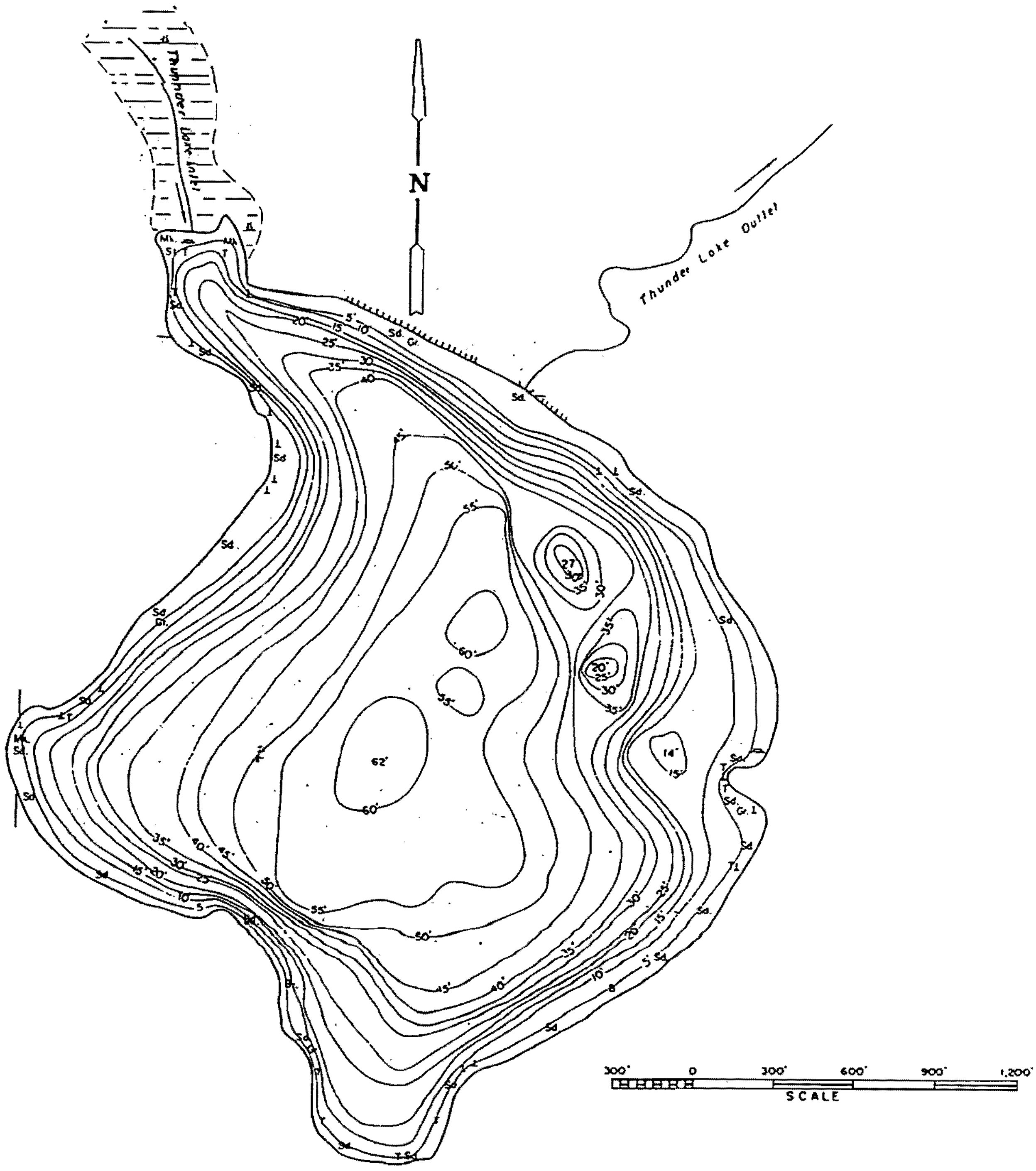


Figure 7. Thunder Lake contour map.

Table 2. Thunder Lake Characteristics

Area (Lake): 134.5 acres (54.4 ha)
Mean depth: 31 feet (9.4 m)
Maximum depth: 62 feet (18.9 m)
Volume: 4,169.5 acre-feet (511.4 Ha-M)
Fetch: 0.63 mile (1.02 km)
Watershed area: 2,508.5 acres (1,015.2 ha)
Watershed: Lake surface ratio 20:1
Estimated average water residence time 1.66 years
Public accesses (#): 1
Inlets: 1 Outlets: 1

Land Use (percentage/area):

	Forest	Wetlands	Urban-Res
Percentage	81	18	1
Acres	2,037	448	23

Development (Homes): 36 + 1 resort

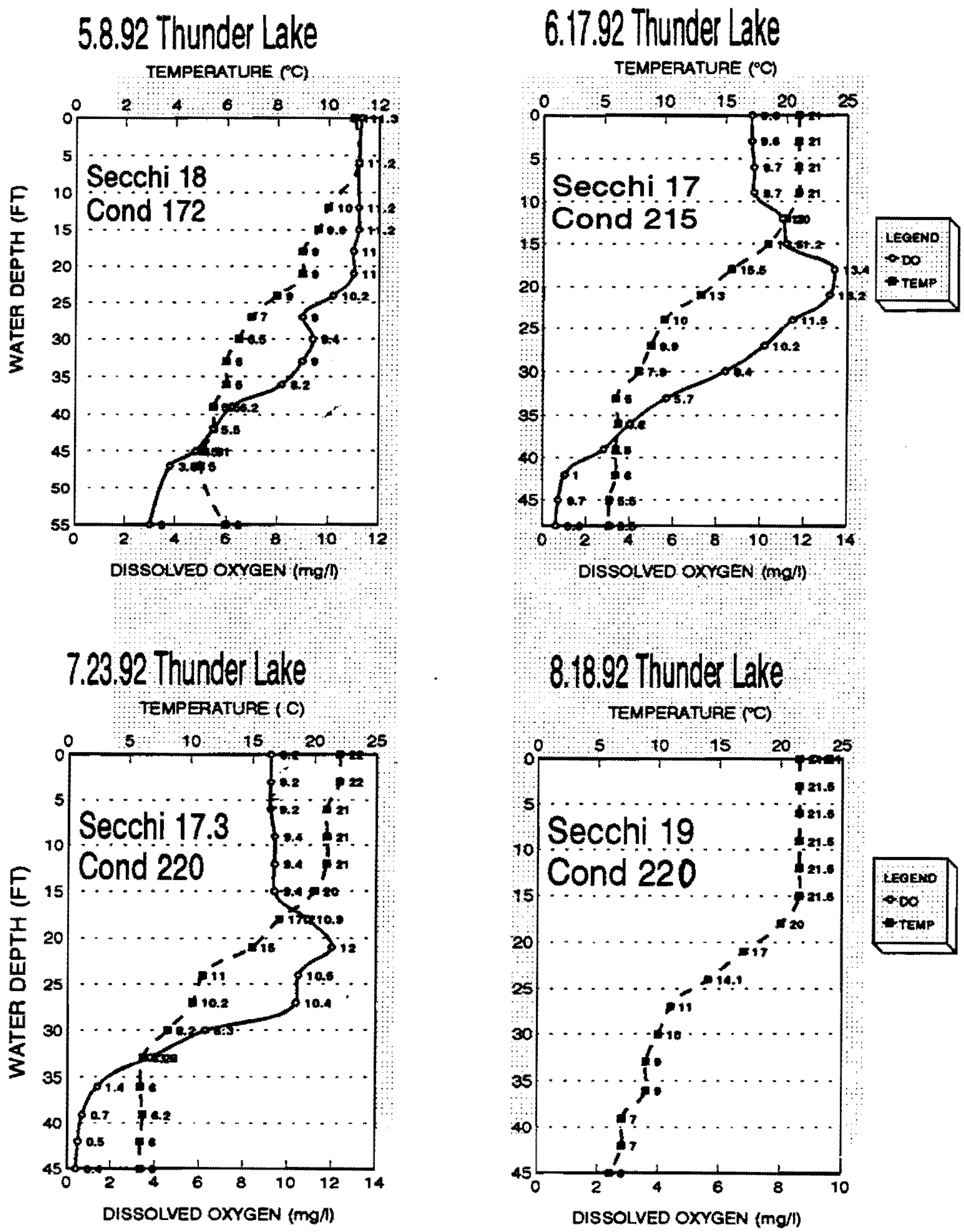


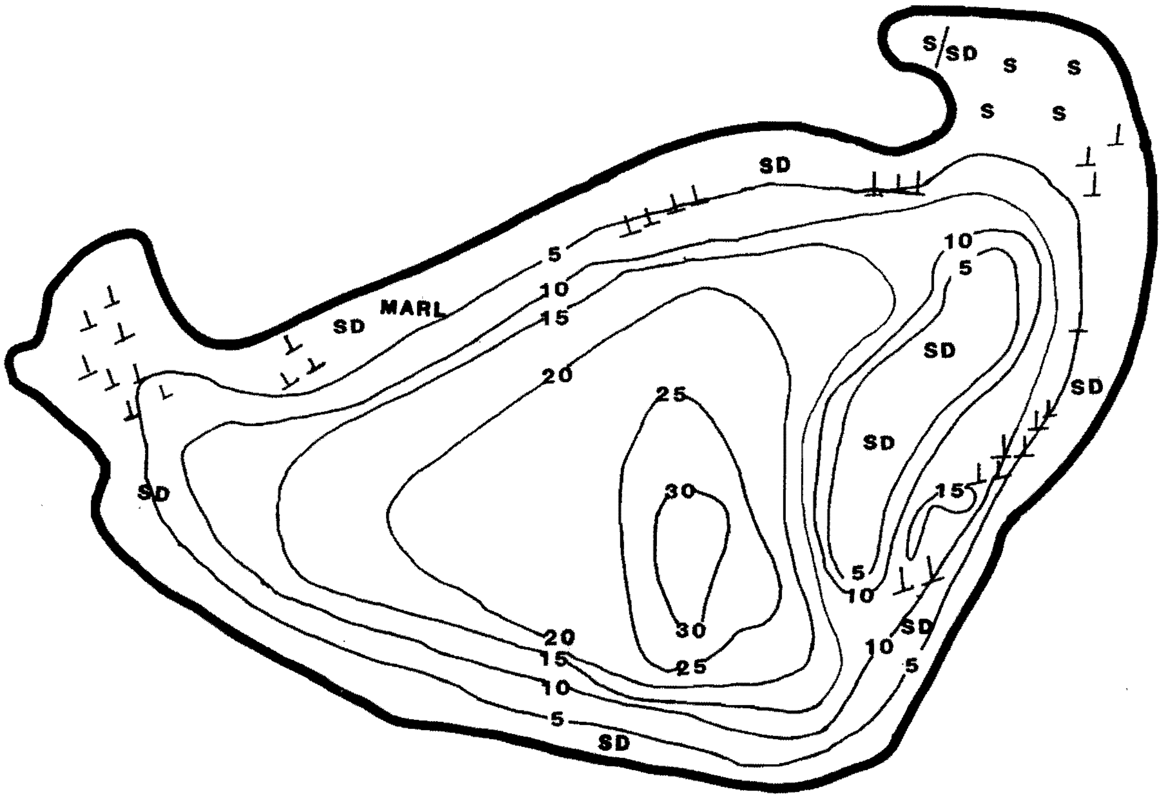
Figure 8. Temperature and dissolved oxygen curves for Thunder Lake, 1992. Secchi disc is in feet and conductivity is microsiemens.

Eagle Lake

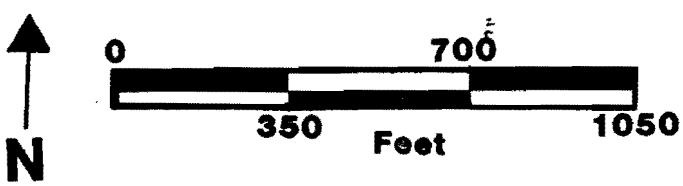
Eagle Lake is 56.3 acres in size, with a watershed of 218 acres. The average depth of Eagle Lake is 1.7 meters (5.5 feet) with a maximum depth of 9.1 meters (30 feet)(Table 3). Eagle Lake is located in an area of Wisconsin that is dominated by forests. The Eagle Lake watershed is 91% forest (198 acres), and 9% wetlands (18 acres)(listed in Table 2 and shown again in Table 3).

The summer dissolved oxygen (DO) and temperature profiles (Figure 7) indicate that in the deeper waters the DO is in good supply. The temperature throughout the water column is relatively constant changing only a few degrees indicating the lake is polymictic and probably mixes occasionally through the summer.

The secchi disc transparency had an average summer depth of 4.8 meters (15.7 feet) in 1991.



Eagle Lake
Marinette County, Wisconsin



Area - 56.3 acres
Max. Depth - 30 feet

Latest Survey - 1992

Water Quality - Clear Water
Seepage Lake: Hard Water

Water Transparency (ft): 16 feet

Total phosphorus (ppb): 10 parts per billion

Map Prepared and Information Compiled by:
BLUE WATER SCIENCE
St. Paul, MN

Depths were determined from transects made by:
Wisconsin Department Of Natural Resources

Table 3. Eagle Lake Characteristics

Area (Lake): 56.3 acres (22.8 ha)
Mean depth: 5.5 feet (1.7 m)
Maximum depth: 30 feet (9.1 m)
Volume: 312 ac-ft (38.53 ha-m)
Fetch: 0.82 mile (1.3 km)
Watershed area: 217.5 acres (88.0 ha)
Watershed: Lake surface ratio 4:1
Estimated average water residence time 0.72 years
Public accesses (#): 1
Inlets: 0 Outlets: 0

Land Use (percentage/area):

	Forest	Wetlands	Urban-Res
Percentage	91	9	0
Acres	198.65	18.85	0

Development (Homes):	Seasonal	Permanent	Total
			4

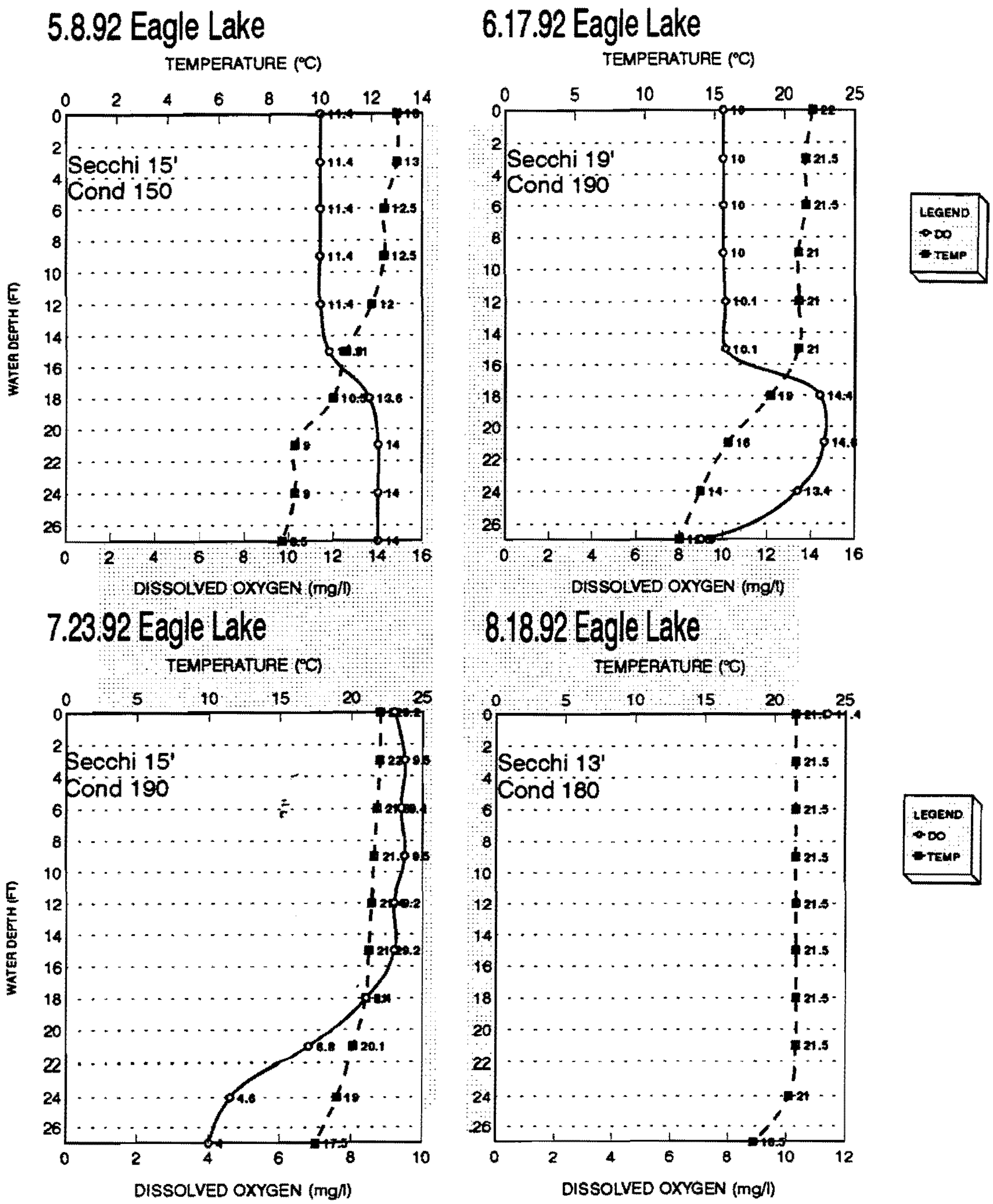
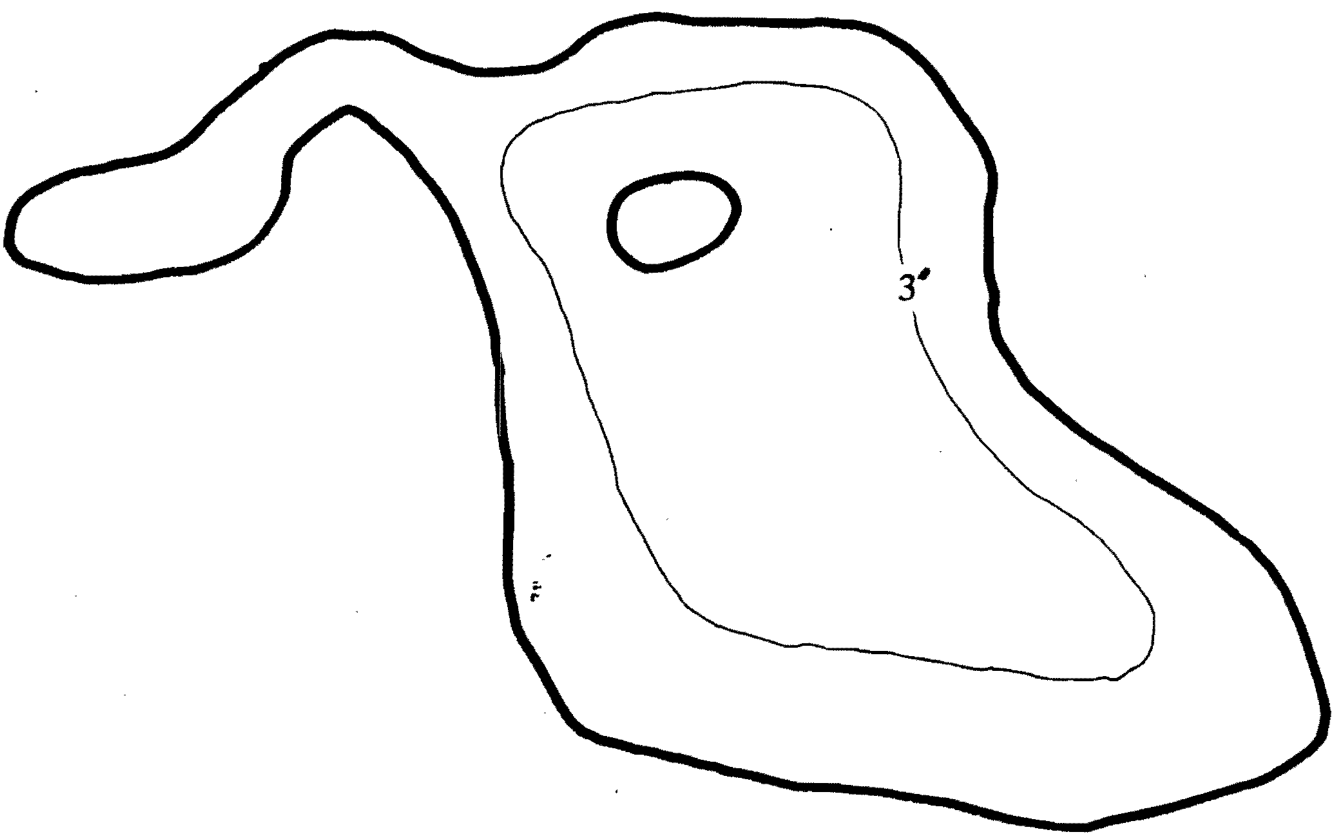


Figure 9. Temperature and dissolved oxygen curves for Eagle Lake, 1992.

Island Lake

Island Lake is 8.9 acres in size, with a watershed of 245 acres. The average depth of Island Lake is 1.7 meters (5.5 feet) with a maximum depth of 3 meters (10 feet)(Figure 8). Island Lake is located in an area of Wisconsin that is dominated by forest. The Island Lake watershed is 100% forest (245 acres)(listed in Table 2 and shown again in Table 4).

The secchi disc transparency had an average summer depth of 2.5 meters (8 feet) in 1992.



Island Lake

Average depth - 5.5 feet

Area - 8.9 acres Max. Depth - 10 ft

Water Transparency (ft) - 6.9

Water Quality: Light brown water color
slightly acid water

Latest Survey - 1992

Figure 10. Island Lake.

Table 4. Island Lake Characteristics

Area (Lake): 8.9 acres (3.6 ha)
Mean depth: 5.5 feet (1.7 m)
Maximum depth: 10 feet (3.0 m)
Volume: 48.95 ac-ft (6.08 ha-m)
Fetch: 0.22 mile (0.37 km)
Watershed area: 245.1 acres (99.2 ha)
Watershed: Lake surface area 28:1
Estimated average water residence time 0.10 years
Public accesses (#): 0
Inlets: 0 Outlets: 0

Land Use (percentage/area):

	Forest	Wetlands	Urban-Res
Percentage	100	0	0
Acres	245.1	0	0

Development (Homes):	Seasonal	Permanent	Total
	0	0	0

Physical/Chemistry Data Emphasizing Phosphorus and Nitrogen for Thunder, Eagle and Island Lakes

Summer water chemistry data collected during 1992 included secchi disc, total phosphorus (TP), chlorophyll a (Chl a), total kjeldahl nitrogen (TKN), ammonia (NH_3), nitrate (NO_3), and conductivity (Cond) (Table 5). Samples were collected at the Thunder Lake inlet and at the surface and two feet off the bottom in the deepest area of Thunder Lake. Total phosphorus was higher in the bottom water than the top water indicating some phosphorus release from the bottom material (sediments or plants) may be occurring. Phosphorus was low in the Thunder Lake Inlet (Thunder Creek).

Table 5. Summertime sample results for Thunder, Eagle, and Island Lake

	TP (top water) ppb	TP (bottom water) ppb	Chl a ppb	SD ft	Nitrite mg/l	TKN mg/l	Cond umhos	Ammonia mg/l
Thunder Lake-Inlet								
Date								
5.8.92	20	20	–	–	0.105	0.2	200	–
6.17.92	14	–	–	–	0.041	0.3	210	0.024
7.24.92	13	–	–	–	0.045	0.3	200	0.029
8.18.92	8	–	3.38	–	0.033	0.2	–	–
Average	14	20	3.38	–	0.06	0.25	203.3	0.03
Thunder Lake								
Date								
5.8.92	20	20	2	18	0.126	0.2	172	–
6.17.92	6	13	3	17	–	0.006	215	0.011
7.23.92	6	53	2.06	17.3	–	0.3	–	0.015
8.18.92	4	4	1.65	–	–	0.2	–	–
Average	9	22.5	2.2	17.4	0.126	0.18	193.5	0.013
Eagle Lake								
Date								
5.8.92	20	20	3	15	0.057	0.6	–	–
6.17.92	6	12	2	19	–	0.3	190	0.016
7.23.92	9	11	1.85	16	–	0.4	–	0.017
8.18.92	6	8	2.99	13	–	0.3	–	–
8.18.92	16	–	–	–	–	–	–	–
Average	10	12.75	2.46	15.75	0.057	0.4	190	0.017
Island Lake								
Date								
5.8.92	20	–	9	–	–	0.4	–	–
6.17.92	25	–	7	–	0.009	0.8	–	0.07
7.24.92	16	–	3.07	–	–	0.8	–	0.022
8.18.92	20	3180*	2.27	7	0.009	0.6	–	–
Average	20	3180*	5.3	7	0.009	0.65	–	0.046

* sediments were stirred up on purpose to see if the sediments were phosphorus enriched.

Trophic State Index

The Trophic State Index (TSI) was calculated for water chemistry results and is shown in Table 6. Results indicate Thunder Lake, Eagle Lake, and Island Lake are mesotrophic lakes (Figure 9). Thunder Lake had the best TSI of the three lakes, followed by Eagle and Island. Although there was some variability within a lake for phosphorus, chlorophyll, and transparency values, they are fairly close.

Table 6. Summary of Trophic State Index Values for Thunder, Eagle, and Island Lakes

	Thunder Lake	Eagle Lake	Island Lake
TSIP (TP)	38	40	50
TSIC (Chl a)	42	42	48
TSIS (Secchi disc)	36	37	49
TSI (mean)	39	40	49

TSI = Trophic State Index

TSI(Chl a)(ppb or ug/L) = $36.25 + 15.5 \log_{10}$ [Chl a]
TSI(TP)(ppb or ug/L) = $60 - 33.2 \log_{10} (40.5/TP)$
TSI(Secchi)(meters) = 60-(SD $\log_{10}$ x 33.2)

$TSI(Chl\ a) = 36.25 + 15.5 \log_{10} [Chl\ a]$
ppb or ug/l
$TSI(TP) = 60 - 33.2 \log_{10} (40.5/TP)$
ppb or ug/l
$TSI(Secchi) = 60 - (SD \log_{10} \times 33.2)$
meters

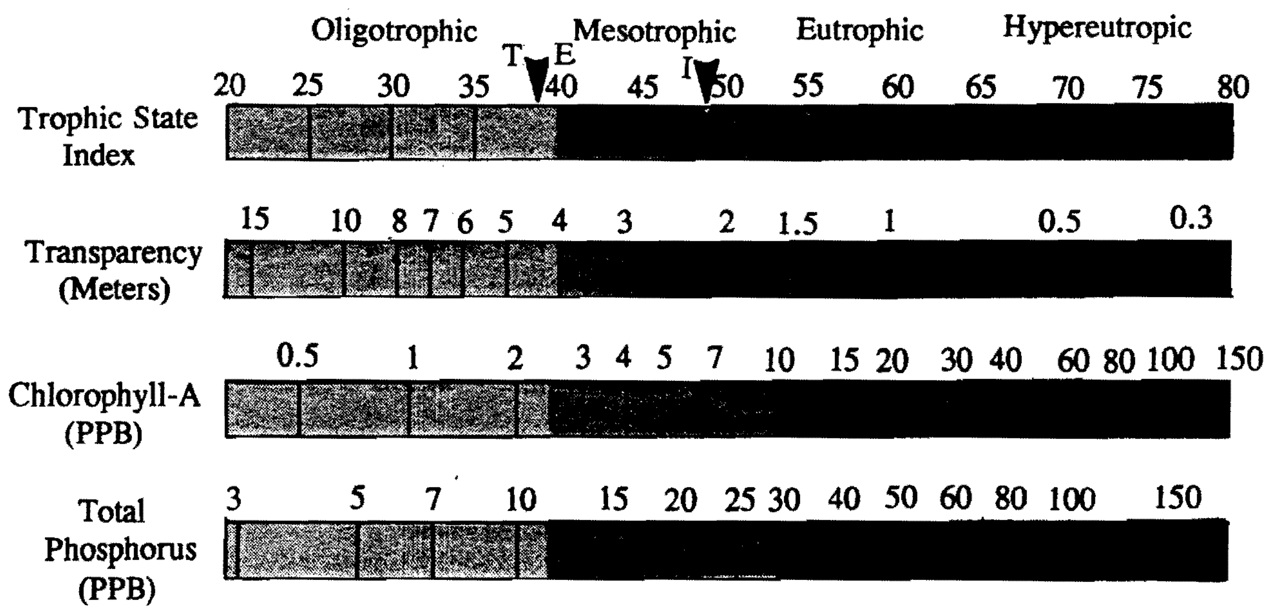


Figure 11. Carlson's Trophic State Index. Taken from NALMS (1988). Each lake's TSI is shown with arrows, T = Thunder Lake, E = Eagle Lake, and I = Island Lake.

Macrophytes

An aquatic plant survey was conducted on Thunder Lake and on Eagle Lake in 1992 and results are shown below.

Thunder Lake

Twenty transects were run with sample points at 0-1.5 feet, 1.5-5 feet, 5-10 feet, and greater than 10 feet. Rooted plants were found in water to a depth of 16 feet. Plant coverage is shown in Figure 10. Plant coverage on the bottom is roughly 8% of the bottom area. Four plant groups are represented, with no group dominating (Table 7).

Table 7. Species list of the aquatic plants found in Thunder lake.

Common Name	Scientific Name
Eurasian watermilfoil	*Myriophyllum spicatum*
Native watermilfoil	*M. exalbescens*
Wild celery	*Vallisneria americana*
Slender naiad	*Najas flexilis*
Hornwort	*Ceratophyllum demersum*
Flatstem pondweed	*Potamogeton zosteriformis*
Illinois pondweed	*P. illinoensis*
Muskgrass	*Chara sp.*
Common waterweed	*Elodea canadensis*
Sago pondweed	*P. pectinatus*

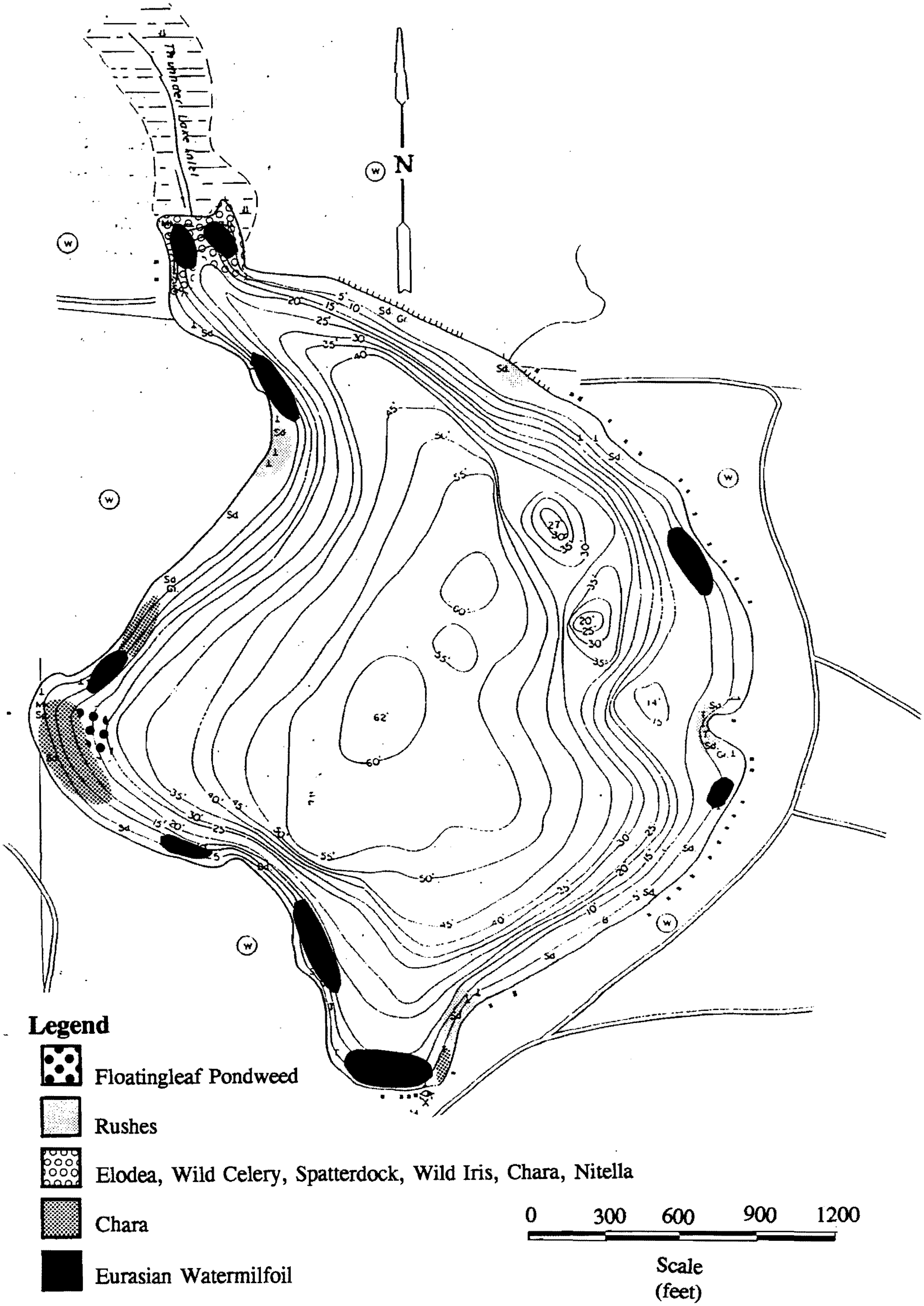


Figure 12. Plant distribution in Thunder Lake, 1992.

Eagle Lake

A modified plant survey was conducted on Eagle Lake. Aquatic macrophytes were not numerous. Rather than taking transects perpendicular to shore, we made a survey that went parallel to shore and then surveyed the entire littoral area for the circumference of the lake.

We have summarized macrophyte findings on Figure 11. Chara was a dominant submerged plant and some floatingleaf pondweed was encountered.

Island Lake

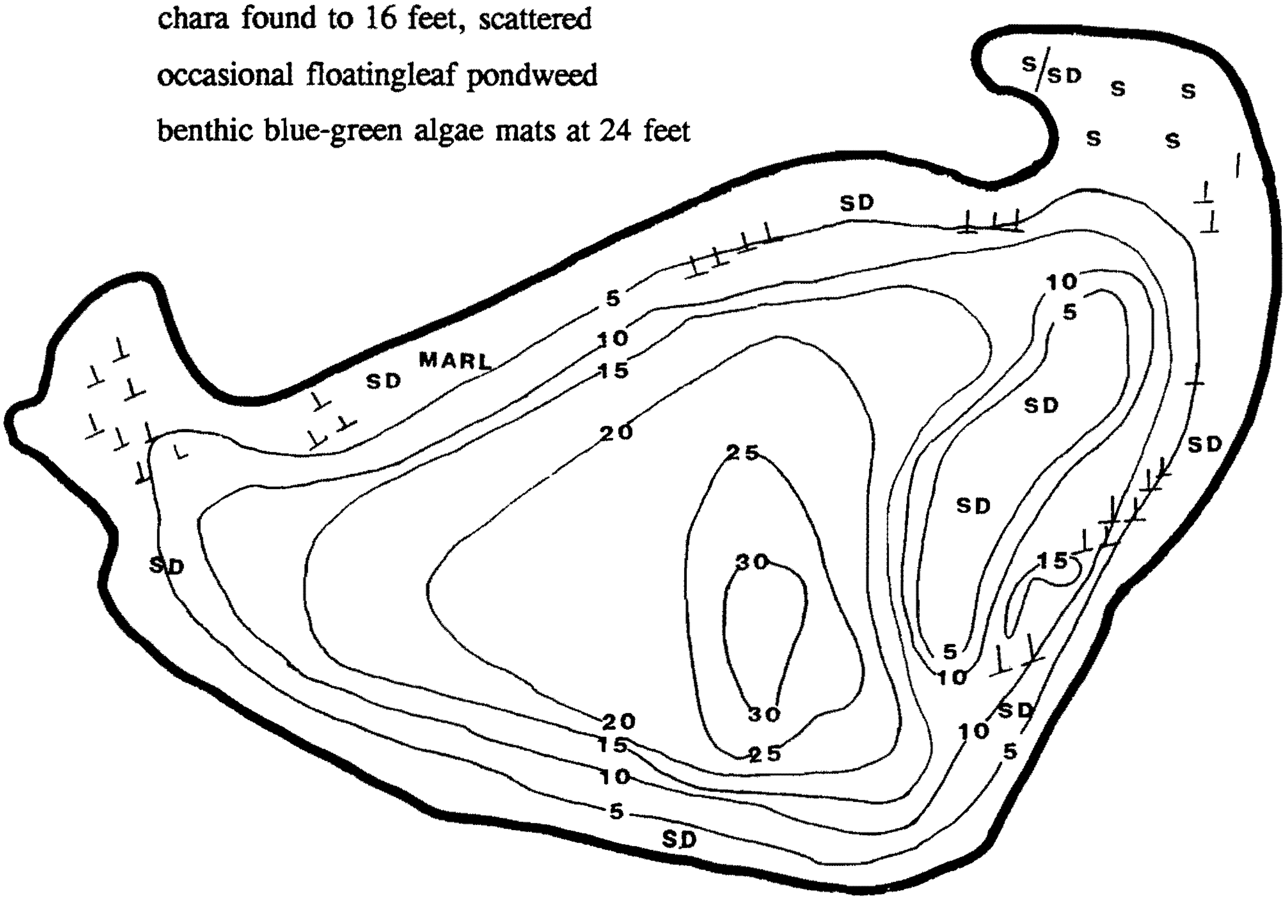
Island Lake is shallow with approximately 90% bottom coverage. Several plants dominate the macrophyte community and plants grow throughout the lake. The macrophyte survey of Island Lake was a combination of a visual inspection from a canoe and then documented by several transects with an underwater video.

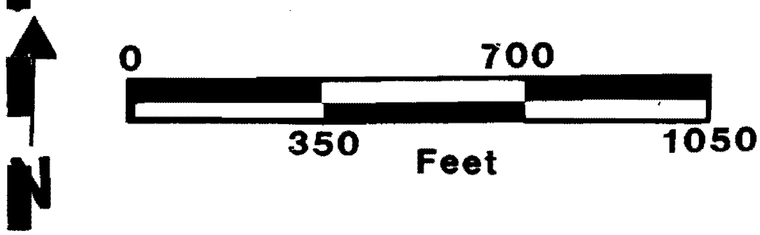
⊥ = rushes/scattered

chara found to 16 feet, scattered

occasional floatingleaf pondweed

benthic blue-green algae mats at 24 feet





Eagle Lake
Marinette County, Wisconsin

Area - 56.3 acres
Max. Depth - 30 feet

Latest Survey - 1992

Water Quality - Clear Water
Seepage Lake: Hard Water

Water Transparency (ft): 16 feet

Total phosphorus (ppb): 10 parts per billion

Map Prepared and Information Compiled by:
BLUE WATER SCIENCE
St. Paul, MN

Depths were determined from transects made by:
Wisconsin Department Of Natural Resources

Figure 13. Plant Distribution in Eagle Lake, 1992.

7. THUNDER LAKE, EAGLE LAKE, AND ISLAND LAKE PHOSPHORUS MODEL

Lake modeling is a tool that aids in predicting what phosphorus concentrations should be in a lake based on the amount of nutrients that comes into a lake on an annual basis. A lake model can also be used to predict what future conditions could be if changes occur in the watershed that bring in more phosphorus.

The phosphorus model used in this study was Canfield and Bachmann Model (1981). The model format is shown in Table 8. Before the models could be run, nutrient and water budgets for Thunder, Eagle, and Island Lakes were needed. To estimate the nutrient budget, phosphorus concentrations were assigned for various land use delineations and then assuming a certain amount of runoff per year we estimated phosphorus inputs from various land uses. A summary of phosphorus export coefficients for each land use and then the total estimated phosphorus input to Thunder, Eagle, and Island Lakes are shown in Tables 9, 10, and 11. The nutrient input table shows that forest land is the major nutrient contributor to Thunder, Eagle, and Island Lakes followed by rainfall and then followed by residential areas and lastly the wetlands systems. The variables with high uncertainty are groundwater inputs as well as septic tank inputs. Our estimates are that septic tanks inputs are relatively low.

The phosphorus model predictions and the actual observed phosphorus load are shown in Table 12.

Table 9. Phosphorus loading, water budget and phosphorus model results for Thunder Lake.

PHOSPHORUS LOADING				
	Export coeff		Area	Phos input
	kg/ha/yr		ha	kg/yr
Forest	0.1		824.65	82
Wetland	0.05		181.3	9
Urban	0.19		9.4	2
Agriculture	1		0	0
Septic Tank Systems				
Seasonal	0.055		35	2
Permanent	0.166		5	1
Rainfall	0.4		54.4	22
Groundwater	0.04		0	0
Misc Phos Input				0
	TOTAL MASS	==>		118

WATER BUDGET			
Avg Runoff, in	12	0.3048	m
Watershed area, ha	2508.5	2508.5	ha
Net Precip, rain - evap, inches	0	0	m
Lake surface area, ha	54.4	54.4	ha
Net water input rainfall, m^3	0		
Net water input, watershed, m^3	7,645,908		
Total Water, m^3 ==>	7,645,908		

Canfield Bachmann Lake Phosphorus Model

Description	Units	Eq. Symbol	Value
Lake Area	ha	A	54.4
Mean Depth	m	z	9.4
Lake Volume	m^3	V	5,113,600
Total P mass	kg/yr	M	117.83
Total Water	m^3	Q	7,645,908
Total TP load	mg/m^2/yr	L	217
Flushing rate	1/yr	P	1.50
Nat Sed coeff	1/yr	SIGMA_n	0.68
Art Sed Coeff	1/yr	SIGMA_a	0.72
Natural Lake Total Phosphorus, ppb			11
Artificial Lake Total Phosphorus, ppb			10

Table 10. Phosphorus loading, water budget and phosphorus model results for Eagle Lake.

PHOSPHORUS LOADING				
	Export coeff kg/ha/yr		Area ha	Phos input kg/yr
Forest	0.1		80.39	8
Wetland	0.05		7.6	0
Urban	0.19		0	0
Agriculture	1		0	0
Septic Tank Systems				
Seasonal	0.055		4	0
Permanent	0.166		0	0
Rainfall	0.4		22.8	9
Groundwater	0.04		0	0
Misc Phos Input				0
	TOTAL MASS	==>		18

WATER BUDGET				
Avg Runoff, in		12	0.3048	m
Watershed area, ha		217.5	217.5	ha
Net Precip, rain - evap, inches		0	0	m
Lake surface area, ha		22.8	22.8	ha
Net water input rainfall, m^3		0		
Net water input, watershed, m^3		662,940		
	Total Water, m^3 ==>	662,940		

Canfield Bachmann Lake Phosphorus Model

Description	Units	Eq. Symbol	Value
Lake Area	ha	A	22.8
Mean Depth	m	z	2.1
Lake Volume	m^3	V	478,800
Total P mass	kg/yr	M	17.76
Total Water	m^3	Q	662,940
Total TP load	mg/m^2/yr	L	78
Flushing rate	1/yr	P	1.38
Nat Sed coeff	1/yr	SIGMA_n	0.85
Art Sed Coeff	1/yr	SIGMA_a	0.96
Natural Lake Total Phosphorus, ppb			17
Artificial Lake Total Phosphorus, ppb			16

Table 11. Phosphorus loading, water budget and phosphorus model results for Island Lake.

PHOSPHORUS LOADING			
	Export coeff kg/ha/yr	Area ha	Phos input kg/yr
Forest	0.1	99.2	10
Wetland	0.05	0	0
Urban	0.19	0	0
Agriculture	1	0	0
Septic Tank Systems			
Seasonal	0.055	0	0
Permanent	0.166	0	0
Rainfall	0.4	3.6	1
Groundwater	0.04	0	0
Misc Phos Input			0
	TOTAL MASS ==>		11

WATER BUDGET			
Avg Runoff, in	10	0.254	m
Watershed area, ha	245.1	245.1	ha
Net Precip, rain - evap, inches	0	0	m
Lake surface area, ha	3.6	3.6	ha
Net water input rainfall, m^3	0		
Net water input, watershed, m^3	622,554		
Total Water, m^3 ==>	622,554		

Canfield Bachmann Lake Phosphorus Model

Description	Units	Eq. Symbol	Value
Lake Area	ha	A	3.6
Mean Depth	m	z	1.7
Lake Volume	m^3	V	61,200
Total P mass	kg/yr	M	11.36
Total Water	m^3	Q	622,554
Total TP load	mg/m^2/yr	L	316
Flushing rate	1/yr	P	10.17
Nat Sed coeff	1/yr	SIGMA_n	1.77
Art Sed Coeff	1/yr	SIGMA_a	2.47
Natural Lake Total Phosphorus, ppb			16
Artificial Lake Total Phosphorus, ppb			15

Table 12. Total phosphorus observed and calculated model predictions

	Total phosphorus
Actual summer Thunder Lake TP	9 ppb
Model prediction	11 ppb
Actual summer Eagle Lake TP	10 ppb
Model prediction	17 ppb
Actual summer Island Lake TP	20 ppb
Model prediction	16 ppb

8. LAKE STATUS

The status of Thunder, Eagle, and Island Lakes is good. Values for phosphorus, chlorophyll and secchi depth are within ecoregion values (Table 13).

Table 13. Summer average water quality characteristics for lakes in the Northern Lakes and Forest ecoregion, as noted in Descriptive Characteristics of the Seven Ecoregions in Minnesota, by G. Fandrei, S. Heiskary, and S. McCollar. 1988. Minnesota Pollution Control Agency.

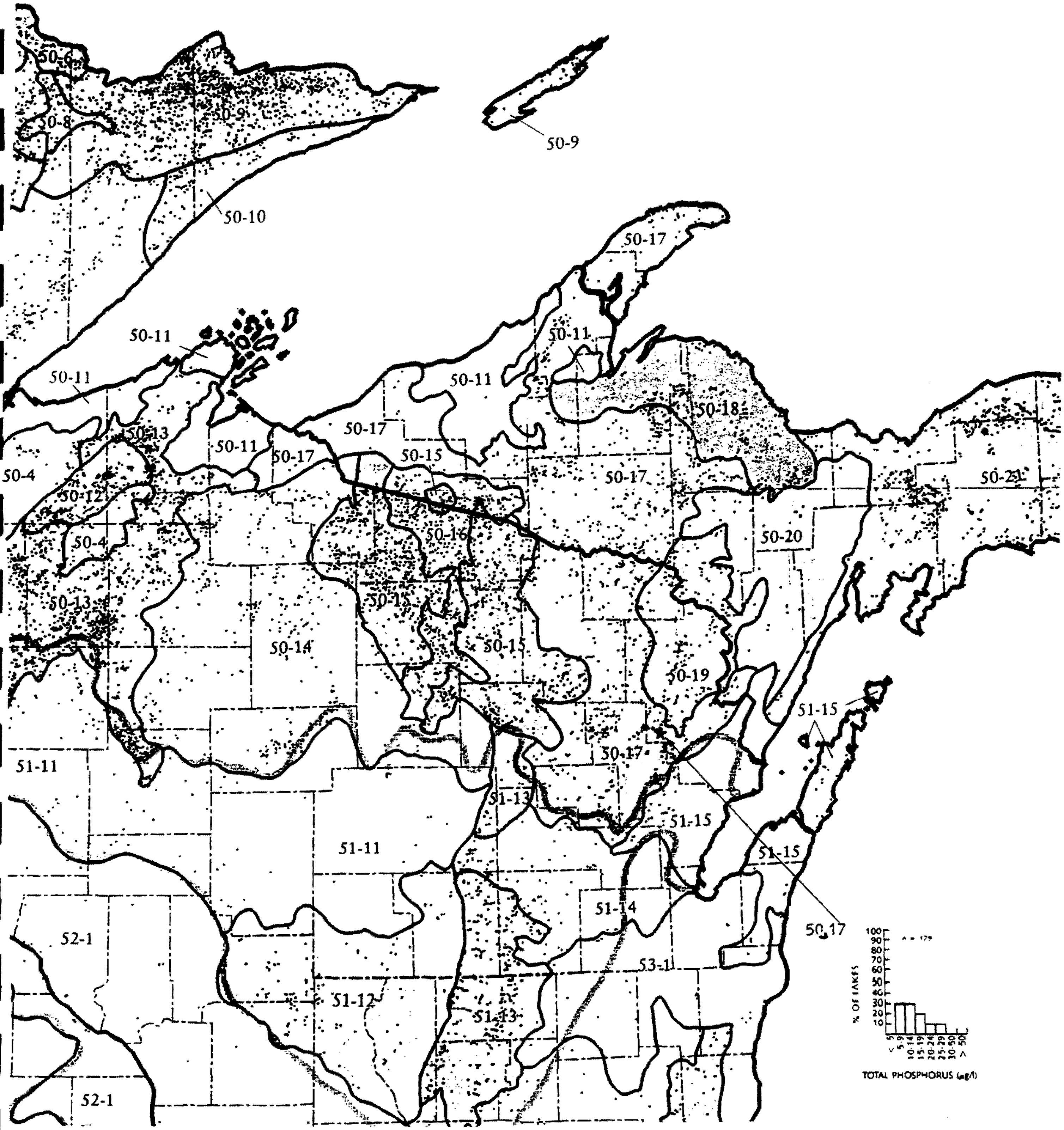
Parameter	Northern Lakes & Forests	Thunder Lake	Eagle Lake	Island Lake
Total Phosphorus (ug/l)				
epilimnion	14-27	9	10	20
hypolimnion	--	23	13	3180*
Chlorophyll mean (ug/l)	<10	2	3	5
Chlorophyll maximum (ug/l)	<15	2	3	3
Secchi disc (feet)	8-15	17	16	7
meters	2.4-4.6	5.2	4.9	2.1
Total Kjeldahl Nitrogen (mg/l)	<0.75	0.18	0.4	0.65
Nitrite + Nitrate N (mg/l)	<0.01	0.126	0.057	0.009
Conductivity (umhos/cm)	50-250	194	190	--
TN:TP Ratio	25:1-35:1	34:1	46:1	33:1

* sediments were stirred up on purpose to see if the sediments were phosphorus enriched.

A map showing the ecoregion area and the Thunder Lakes location is displayed in Figure 12. Phosphorus concentrations were generally less than 29 ppb. Thunder, Eagle and Island Lake have phosphorus concentrations less than 29 ppb.

These comparisons indicate that the Thunder Lakes are definitely in a protection status in terms of water chemistry, meaning no drastic lake or watershed restoration projects are needed. At this point in time the challenge is to keep the lakes in good shape.

Although Eurasian watermilfoil is a nuisance in Thunder Lake, it is not threatening the lake's water quality.



Source: Summer Total Phosphorus in Lake in Minnesota, Wisconsin, and Michigan. J.M. Omernik, C.M. Rohm, S.E. Clarke, and D.P. Larsen. EPA. Environmental Management, Vol. 12, No. 6. Nov. 1988.

Figure 14. Summertime total phosphorus in the Thunder Lakes study area.

An important component to watch and to control is nutrient inputs -- both phosphorus and nitrogen. All three lakes presently have clear water. If phosphorus concentrations increase to around 40 ppb or above, nuisance algae blooms could develop, and this could cause a cascade of problems.

The estimated amount of additional annual phosphorus inputs to this three lakes to initiate algae problems is shown in Table 14.

Although Thunder Lake can assimilate more phosphorus than the other two lakes, it is still very vulnerable. A doubling or tripling of phosphorus concentrations in Thunder Creek could spell trouble for Thunder Lake. This could easily occur if proper watershed management is not implemented.

Table 14. Estimated increases in annual phosphorus inputs that could cause nuisance algae concentrations.

Lake	Current Estimated Annual P Inputs	Predicted P Conc W/Input	Estimated P Input to Cause Nuisance Algae Concs	Predicted P Conc W/Input	Increase In Annual P Inputs To Cause Nuisance Algae Concs
Thunder	118 kg	11 ppb	598 kg	40 ppb	470 kg
Eagle	18 kg	17 ppb	53 kg	40 ppb	36 kg
Island	11 kg	16 ppb	32 kg	40 ppb	21 kg

Likewise, construction and lake resident activities can have significant impacts on phosphorus inputs. Studies in Maine show that clearing the trees off your property, even a partial clearing can increase phosphorus inputs to the lake from the runoff. Eagle and Island Lakes are vulnerable to an increase in phosphorus inputs, and therefore shoreland nutrient inputs could be significant and contribute to water quality degradation. Shoreland projects to reduce nutrient inputs are important.

9. MANAGEMENT PLAN FOR THUNDER, EAGLE, AND ISLAND LAKES

A list of projects has been prepared that are intended to protect the water quality of the Thunder Lakes. Projects are listed below:

County-level

1. Adopt an ordinance for erosion control of Construction sites.
2. Adopt an ordinance for maintaining and upgrading septic tanks.

Local level (Shoreline Best Management Projects)

3. Aquascaping/native plant reestablishment.
4. Eurasian watermilfoil control.
5. Landscaping for wildlife.
6. On-site system maintenance program.
7. Lake shoreland projects.
8. Continue a lake monitoring program.

Details of these projects are given in the following pages.

General Criteria for Erosion Control at Construction Sites

CRITERION 1 — Stabilization of denuded areas and soil stockpiles

A. *Permanent or temporary soil stabilization must be applied to disturbed areas within two weeks after rough grading.* Soil stabilization refers to measures which protect soil from erosive forces of raindrop impact and flowing water. Applicable practices include vegetative establishment, mulching, erosion control blankets, and early application of gravel base on areas to be paved. Soil stabilization measures should be selected to be appropriate for the time of year, site conditions, and estimated duration of use.

B. *Soil stockpiles must be established or protected with sediment-trapping measures to prevent soil loss.*

CRITERION 2 — Establishment of permanent vegetation

A permanent vegetative cover shall be established on denuded areas not otherwise permanently stabilized. Permanent vegetation shall not be considered established until a ground cover is achieved which is mature enough to control erosion satisfactorily.

CRITERION 3 — Protection of adjacent properties

Properties adjacent to the site of a land disturbance shall be protected from sediment deposition. This may be accomplished by preserving a well-vegetated buffer strip around the lower perimeter of the land disturbance, by installing perimeter controls such as sediment barriers, filters, dikes, or sediment basins, by stockpiling soil in appropriate locations, or by a combination of such measures.

CRITERION 4 — Timing and stabilization of sediment-trapping measures

Detailed construction schedules shall be submitted as part of the Erosion and Sediment Control plan. Construction schedules include

- when the construction of sediment-trapping measures will occur,
- stabilization of the earthen structures, and
- the timing of construction phases and grading phases.

CRITERION 5 — Use of sediment basins and nutrient traps

Stormwater runoff from drainage areas with five acres or greater disturbed area must pass through a sediment basin or other suitable sediment trapping facility with equivalent or greater storage capacity. There are several options available for basin design. These standards may be updated as more basin specifications are tested.

CRITERION 6 — Cut and fill slopes

Cut and fill slopes must be designed and constructed in a manner which will minimize erosion. Consideration must be given to the length and steepness of the slope, the slope type, upslope drainage area, groundwater conditions, and other applicable factors. Guidelines are provided to aid in developing of an adequate design.

CRITERION 7 — Storm management criteria for controlling off-site erosion

Properties and waterways downstream from development sites shall be protected from erosion due to increases in the volume, velocity, and peak water flow rate of stormwater runoff.

A. *Concentrated storm runoff water leaving a development site must be discharged directly into a well-defined natural or man-made off-site receiving channel or pipe.* If there is no well-defined off-site receiving channel or pipe, one must be constructed to convey storm water to the nearest adequate channel. Newly-constructed channels shall be designed as adequate channels.

CRITERION 8 — Stabilization of waterways and outlets

All on-site storm water conveyance channels shall be designed and constructed to withstand the expected velocity of flow from a 2-year frequency storm without erosion. Stabilization adequate to prevent erosion must also be provided at the outlets of all storm sewer pipes.

CRITERION 9 — Storm sewer inlet protection

All storm sewer inlets which are functioning during construction shall be protected so that sediment-laden water will not enter the conveyance system without first being filtered or otherwise treated to remove sediment. The use of inlet filters can usually be avoided if other strategies are implemented that keep sediment from entering streets. If a site is properly seeded and slope lengths are short, then the sediment runoff will be substantially reduced. If a site will require inlet filters, the proper detail should be shown on the plan.

CRITERION 10 — Working in or crossing waterbodies

Where work is necessary adjacent to a waterbody, precautions must be taken to contain sediment, stabilize the work area during construction to minimize erosion, and restabilize the work area within one week.

CRITERION 11 — Underground utility construction

All areas disturbed by utility construction shall be restabilized; and if dewatering services are used, adjacent properties shall be protected.

CRITERION 12 — Construction access routes

Whenever construction vehicle access routes intersect paved public roads, provisions must be made to minimize the transport of sediment (mud) by runoff or vehicle tracking onto the paved surface. Where sediment is transported onto a public road surface, the roads should be cleaned thoroughly at the end of each day. Sediment should be removed from roads by shoveling or sweeping and be transported to a controlled sediment disposal area. Street washing should be allowed only after sediment is removed in this manner.

The plan must show on a detailed drawing where the entrance point(s) will be located.

CRITERION 13 — Disposition of temporary measures

All temporary erosion and sediment control measures can be disposed of within 30 days after final site stabilization is achieved or after the temporary measures are no longer needed. Trapped sediment and other disturbed soil areas resulting from the disposition of temporary measures should be permanently stabilized to prevent further erosion and sedimentation. A contact person should be specified on the plan.

CRITERION 14 — Maintenance of practices

All temporary and permanent erosion and sediment control practices must be maintained and repaired as needed to assure the continued performance of their intended function

A contact person, to handle maintenance questions during the various phases of construction, should be specified on the plan.

(Source: Protecting Water Quality in Urban Areas. Minnesota Pollution Control Agency, 1989)

2. Management of On-Site Systems

The goal is to have all on-site systems conforming to code. To accomplish this, an ordinance may have to be implemented. An example of an ordinance for addressing failing on-site systems is shown below (ordinance is from Rice County, Minnesota).

Replacement of Failing Septic Systems

Transfer of Property. A failing on-site sewage treatment system, as defined in Section 710.04 (Minnesota Rules) shall be brought into compliance with this Ordinance when a Transfer of Property occurs after January 1, 1992. The seller shall obtain a "Septic System Evaluation" from the Department (or Environmental Health). The seller shall be responsible for all costs associated with the evaluation of the existing on-site sewage treatment system. All costs associated with the repair or replacement of a failing on-site sewage treatment system shall be the responsibility of the seller, or as otherwise provided for in written agreement between the seller and buyer. The Department shall not require the re-evaluation of an on-site evaluation date. If the property for which an evaluation is being requested is also being offered for sale, a failing on-site sewage treatment system shall be brought into compliance with this Ordinance within ninety (90) days. The Department will give consideration to unique conditions as compliance dates are established.

Complaint Investigation. When sewage, septic tank effluent, or seepage from a soil treatment system is found to discharge into a well, onto the surface, or into bodies of surface water, the existing on-site sewage treatment system shall be replaced with an on-site sewage treatment system which conforms to this Ordinance. The owner(s) shall submit to the Department an acceptable Replacement Plan within twenty (20) days after notification by the Department. The Replacement Plan shall identify the location and design of the on-site sewage treatment system and a schedule for its replacement. Failure to submit and execute an acceptable Replacement Plan is a violation of this Ordinance.

Replacement of Non-conforming Septic Systems. In designing Shoreland Management Areas, failing and non-conforming on-site sewage treatment systems shall be reconstructed pursuant to Minnesota Rules Chapter 6120 and Rice County Shoreland Zoning Ordinance.

For the Thunder Lakes' watershed the two biggest problem conditions for on-site systems are soils that are a poor filter and groundwater that is too close to the surface. Remedies for these problems include pressure distribution, water conservation, black water/gray water separation, curtain drains, mound systems, holding tanks, outhouse, clusters systems, pressure sewers, small diameter gravity, and conventional sewers. Descriptions of these types of systems are given in the following pages.

Pressure Distribution

In coarse soils with rapid infiltration or in tight soils with slow infiltration, a pump or a siphon can be used to distribute effluent uniformly through all the drainfield pipes. The effluent should infiltrate evenly through the soil rather than puddling up and infiltrating only at the point of leaving the septic tank. Pressure distribution is not recommended for extremely coarse soils, but it works in soils having moderately rapid infiltration. In tight soils, an even distribution will yield the full potential of effluent infiltration.

Pressure distribution reduces the problem of overloading an area, results in better treatment, and allows the drainfield to be the same size as a conventional field. The drainfield pipes must be level to insure even distribution, and some mechanical problems may occur with the pump over time. Pressure distribution will cost about $1,200 in addition to the cost of the on-site system.

Water Conservation

Water conservation, in this case, refers to measures that reduce water use in the home. Studies show that individuals use 60 to 150 gallons of water each day, so a family of three will use 180 to 450 gallons of water daily. At a lake cabin with an on-site systems, the drainfield has to be adequate to handle this water. In tight soils, where infiltration is slow, the drainfield may become soggy, which is technically a failure. On small lots, if a smaller-than-average drainfield is all you have, then a smaller-than-average flow should be sent to the drainfield.

Flow saving devices are available for showers, sinks, toilets, and washing machines. Studies indicate that flow reduction devices can cut an individual's water use in half - to approximately 30 gallons a day. Water conservation takes some getting used to, but it is viable option and can be practiced even if you don't have a drainfield problem. Water conservation extends the life of submersible water pumps and wells and does not cause any drastic lifestyle changes.

Some drawbacks to water conservation are that it does cost money to install flow reduction devices, and in extreme cases, septic system effluent can become too concentrated, with higher than normal pollution concentrations. Sometimes the pollutants (for example, phosphorus) are not treated as effectively as they would be in normal concentrations.

Blackwater/Graywater Systems

Blackwater and graywater systems refer to separating a home's wastewater flows into two components: blackwater, which is toilet waste, and graywater, which is everything else. Blackwater wastes are piped to an outdoor holding tank, while the graywater is treated with a conventional septic tank and drainfield system. Assuming that flow reduction devices are already in place, this arrangement further reduces the volume of wastewater to be treated by a drainfield and the volume of water delivered to the holding tank.

Because this system reduces the volume of wastewater to be treated in the drainfield, a smaller drainfield may be installed. And because blackwater goes to a holding tank rather than the drainfield, the nutrient and bacteria loads delivered to the drainfield are likewise reduced. In addition, the system may pay for itself. Compared to a conventional holding tank that receives both blackwater and graywater, the blackwater holding tank will not have to be pumped so frequently.

One of the main drawbacks of blackwater/graywater systems is the expense to retrofit the system on older residential sites. New plumbing and a new holding tanks are required at start-up, and there will be the continuing expense of pumping the holding tank.

Curtain Drains

A curtain drain, also referred to as a french drain, is a four-inch pipe with holes in it, which is buried around the perimeter of the drainfield to intercept seasonally high groundwater and drain it away. The curtain drain should maintain the groundwater table three or four feet below the drainfield area. The septic system effluent can then be treated in unsaturated (non-waterlogged) conditions. Curtain drains, which should be at least 10 feet from the boundary of the drainfield, require permeable soils and a large enough lot to accommodate the drains. Regulations must also allow a surface discharge.

Under the right site conditions, a curtain drain may be a better alternative than a mound system. The curtain drain is a passive system; it does not require pumps. The cost is roughly $1,000 for pipe and installation.

Mound Systems

A mound system is basically a heap of sand, rocks, and dirt with a septic tank drainfield installed in it. The effluent pumped into the elevated drainfield filters through the rocks and sand and is mostly rehabilitated before it hits the original ground surface. The mound system is used in areas with high groundwater tables or where bedrock is close to the surface -- situations in which it is not feasible to install a subsurface drainfield because you lack three or four feet of unsaturated soil above the groundwater or bedrock.

Although a mound system is good in theory, it doesn't always perform satisfactorily. The primary problem is seepage or discharge at the toe (where the mound meets the original ground surface). A pressurized distribution system is used that evenly distributes the effluent through the mound to reduce potential seepage. You will increase your odds of a successful installation by using an experienced contractor. Because of operational difficulties some regulatory agencies allow mound systems as replacements for existing, failing systems but frown on them for new construction. Mound systems cost $6,000 to $10,000 depending on the size and site conditions.

Holding Tank

When site conditions prohibit the installation of a drainfield, holding tanks are sometimes an alternative. A holding tank is a watertight storage tank that receives all wastes and wastewater used in a residence. When the tank is full, the wastes have to be pumped out. Holding tanks are not a desirable option as a replacement system, and they are often not allowed in new construction.

The chief benefit of a holding tank is that its use permits a household to maintain running water. The pumping expense is a major drawback. A 2,000 gallon holding tank serving a family of 3 will need pumping every 10 days (with an average use of 66 gallons a day by each person). If the family practices water conservation, this requirement could be stretched to every 20 days. Clearly, holding tanks are not an optimal long-term wastewater treatment alternative.

Outhouse

If conventional on-site systems are not feasible on your lot, the outhouse may be an alternative. In the past, many outhouses consisted of a hand-dug pit covered by a small solids, but the effluent flows to a holding tank equipped with a pump. Water level controls in the holding tank activate the pump (usually a centrifugal pump), which than pumps the effluent through a pipe to an off-site treatment location. This site can be up to several miles away in a large community drainfield or in a lagoon-type system. This kind of pressure sewer arrangement is referred at as a septic tank effluent pump (STEP) system.

Another pressure sewer arrangement is the grinder pump (GP) system. In this system, solid and liquid household wastes go into a holding tank and a heavy duty grinder pump pumps all the waste through a PVC pipe to a treatment site. In this case a community drainfield cannot be used, and conventional wastewater treatment is required. Grinder pump systems often rely on the old septic tank as an emergency storage tank in case the system breaks down.

Pressure sewers are appropriate for lake communities that have hilly terrain, poor soils, small lots, and fairly dense development. An advantage of pressure sewers over gravity sewers is that because the effluent in the pipes is under pressure, it will go uphill. Therefore, pressure sewers can be buried below the frost line and follow the topography. Gravity sewers, on the other hand, must have a downslope gradient. Sometimes gravity sewers must be dug 20 to 30 feet deep to maintain the correct slope; otherwise, a lift station is required.

Pressure sewer systems are a combination of on- and off-site wastewater treatment. They should be used when individual drainfield treatment is not feasible.

Pressure sewers are more expensive than individual on-site treatment systems, but cheaper than conventional sewers. Pressure sewers prevent groundwater contamination of drinking water wells and the lake by pumping septic tank effluent away from the lake community. When STEP systems are employed, septic tank effluent is not as concentrated as full strength wastewater, and less treatment is required because the solids remain in the septic tank; only the effluent is sent for treatment. When GP systems are used, both solids and liquids are pumped to a treatment area.

Pressure sewers have high operation and maintenance costs associated with mechanical equipment. They also require that a sanitary district be formed to administer maintenance and billing. When used in conjunction with STEP systems, septic tanks still need to be pumped periodically. In GP systems, fibrous material tends to clog the system --

so frequent maintenance is needed to unclog the pipes.

Small Diameter Gravity Sewers

Small diameter gravity sewers are four or six-inch sanitary sewers that carry septic tank effluent by the force of gravity to a treatment site. Occasionally, in the gravity sewer system lift stations (pumping stations) must be used to pump effluent over a hill. Small diameter gravity sewers are similar in concept to STEP systems; solid wastes remain in the septic tank and only the effluent passes into the sewer line. Unlike the STEP system, however, gravity systems are not pressurized, so they rely on downward slopes to get the effluent to lift stations and the treatment site. If a lake community needs to carry septic tank effluent off-site over fairly level land, small diameter gravity sewers ar an option.

Small diameter gravity sewers can be expensive in hilly areas. For lake communities in hilly terrain, deep cuts may have to be made -- 20 or 30 feet deep -- to maintain the downward slope. Solids that remain in septic tanks will also have to be pumped.

Conventional Centralized Treatment

A rural lake community rarely starts out with a centralized sewer system. Converting to a conventional, centralized treatment system involves abandoning septic tanks altogether, installing gravity sewers (usually 8 inches in diameter), and constructing a wastewater treatment facility. The decision to convert a lake community from on-site systems to a centralized sewer system is difficult and often controversial. The conversion is appropriate if the lake community is developing rapidly, with high density, and if a wastewater treatment plant with sufficient capacity exists in the region. Under these conditions, the decision to proceed with centralized sewers may not be too controversial.

The decision to centralize is more difficult for rural communities with no wastewater treatment facility in the area. Factors to consider include the following:

- how well the existing systems function, and how much it would cost to fix the bad ones;
- the housing density around the lake and its projected growth over the next 20 years if sewers are not put in (installing sewers often increases development);
- the condition of the drinking water and effects of the existing system on the

lake; and lastly,

- how the lake residents would respond to the financial burden involved in constructing and operating a centralized sewer system.

The benefits of conventional centralized treatment are that its technology and construction practices are well established, and it is a long-term solution to on-site wastewater treatment system problems. The decision to construct a conventional centralized treatment system is controversial, however, because this system is usually the most expensive wastewater treatment alternative. It can be a financial hardship for some lake residents, and the installation of centralized sewers usually increases development around the lake.

Centralized sewer systems are more acceptable for lake communities with encroaching urbanization than for rural lake communities. In rural areas, it is usually more cost effective to fix the problems in existing on-site systems -- or to serve a portion of the lake with pressure sewers and cluster systems -- than to convert the whole lake to a centralized gravity sewer system.

LOCAL LEVEL PROJECTS (Shoreland Best Management Projects)

3. Aquascaping/Native Plant Reestablishment.

For long term success of a lake improvement project, its essential that Thunder Lake maintains a diverse aquatic plant community. Often, a seed bank is already present in a lake, and disturbed areas will be recolonized naturally. When this does not occur, transplanting desirable submerged aquatic plants as may be the solution. This process is called aquascaping. The species being considered are chara, northern watermilfoil and various Potamogeton pondweeds that are native to the area.

Fact sheets are available concerning aquatic plant plantings. The fact sheets contain examples on what type of aquatic plant grows in what depth of water and some planting instruction.

4. Eurasian Watermilfoil Control

Eurasian watermilfoil (EWM), is present in Thunder Lake, but absent in Eagle and Island Lakes. In Thunder, EWM is a nuisance is some areas. Unless Thunder Lake becomes more nutrient enriched, EWM will probably not colonize much more shoreline areas. A fact sheet on EWM has been prepared for Thunder Lake, that describes its basic ecology as well as some control approaches.

Handpulling and cutting with biomass removal should allow residents to use near shore areas. Mechanical harvesting in the boat landing area may remove the plant canopy, and allow boats to easily get in and out.

5. Landscaping for Wildlife.

The careful planting of selected land plants and aquatic plants can improve water quality by reducing nutrients that run into the lake (land plants) and by taking up nutrients and by stabilizing bottom sediments (aquatic plants). Examples of typical plants are shown in the fact sheets that will be available to lake association members. Another benefit is planned landscaping can enhance wildlife by creating refuges and food sources for water fowl and aquatic animals. The combination of landscaping and aquascaping is appropriate for wetlands, streams, and lakes. For this project we are encouraging the use of vegetative buffers to help reduce erosion and nutrient inputs to the lakes.

Some benefits of this approach are:

- Erosion can be a problem nearly anywhere in the watershed. It is especially critical adjacent to a water body because sediment delivery rates are so high. Landscaping upland areas may not only reduce soil erosion, but may reduce the use of fertilizer as well. Aquascaping is a form of erosion control in the nearshore areas of lakes, and can be used on stream banks as well. Aquatic vegetation can stabilize nearshore areas.

- In some cases, it has been found that aquatic plants can transfer oxygen from the water column down to the roots and aerate the surrounding sediments. This can help reduce phosphorous release from the sediments and improving water quality. To be effective this "natural aeration" effect should be done on a broad scale.

- Transplanting native terrestrial and aquatic plants also aids in reestablishing native plants that have disappeared from the area. One of the objectives of this project is to see if homeowners can reestablish native vegetation in their nearshore areas.

Several Fact Sheets have been prepared that give instructions on planting upland plants.

6. On-site System Maintenance Program.

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 Thunder Lake today.

However, problems can develop if the on-site system has not been designed properly or well-maintained. Around Thunder 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 Thunder Lake Watershed 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

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

- ORDINANCE IMPLEMENTATION

  Work to implement a County Ordinance, where septic systems must be "evaluated" at the time a property is transferred. The seller would obtain a septic system evaluation from Marinette County at the time of property transfer. The evaluation would determine if the septic system was "failing", "non-conforming", or "conforming". A "failing" septic system includes septic systems that discharge onto the ground surface, discharges into tiles and surface waters, and systems found to be contaminating a well. The County would require a "failing" system to be brought into compliance with the Marinette County Ordinance within 90 days of property transfer. A dry well, leaching pit, cesspool, or a septic system drainfield with less than 3-foot vertical separation instance from the bottom of the drainfield to the seasonal high water table or saturated soil conditions would be "non-conforming", but not required to be upgraded at property transfer under the Marinette County Ordinance.

Through these County property transfer requirements a percentage of the septic systems that are not failing but are "non-conforming" would be upgraded to "conforming" if a prospective buyer was applying for a mortgage because the potential buyer's lending institution in some cases will not approve the buyer's loan request because the property to be purchased does not have a conforming septic system. The County's evaluation report would state whether or not the evaluated septic system is "conforming" or "non-conforming".

7. Lake Shoreland Projects.

Activities associated with lakeshore development can impact a lake in many ways. As cabin or home construction increases around a lake, lawns are installed and fertilized. Wetlands may have been filled in the past thus removing some natural filtering action. Rooftops, driveways, sidewalks, and roads increase impervious surfaces. Impervious surfaces are surfaces that prevent runoff from infiltrating into the soil. When runoff doesn't infiltrate the amount of runoff increases, and this water picks up extra nutrients and sediments and delivers them to the lake. Another factor is when the runoff doesn't infiltrate into the soil, it is not very well filtered in the surface runoff.

So development around a lake can increase nutrient and sediment inputs to a lake compared to undeveloped conditions. However, cabin owners can implement some projects to minimize adverse impacts on their lake. That is what this alternative is about; the little things that can be done; and although they may seem trivial, everything is cumulative. For example, if each cabin owner could reduce phosphorous inputs to the lake by 1 pound/year, that may not sound like much. But look at it from the perspective of 30 or 40 cabin owners over 10 years. That represents 400 pounds of phosphorous that has not reached the lake.

8. Continue a lake monitoring program.

To evaluate Thunder, Eagle and Island Lakes, a monitoring program should be ongoing. This program will address the issues of:

- Effectiveness of watershed projects in regard to phosphorus in runoff
- Changes in lake quality as measured by total phosphorus, secchi disc, algae and macrophyte distribution.

Lake Monitoring Details

Secchi Disc transparencies should be taken through the summer monthly.

The surface water samples should be analyzed for the total phosphorus, total nitrogen, and chlorophyll a.

University of Wisconsin-Stevens Point has a very good lake testing program. Lakes are sampled in the spring and the fall and costs are about $120 per lake per year. Citizen volunteers can take the water samples. The UW-Stevens Point contact is Byron Shaw.