Phase I: Water Quality Study of Little Ripley Lake

Little Ripley Lake Management Plan

Prepared for
Shell Lake Inland Protection and Rehabilitation District

July 1998

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Executive Summary

Data collected during 1997 were evaluated to determine the lake's current water quality. To determine the nutrient-limiting algal growth in Little Ripley Lake, To determine the nutrient-limiting algal growth in Little Ripley Lake, nitrogen to phosphorus ratios (i.e., N:P ratios) were evaluated and the average N:P ratio determined (i.e., 23.7). Based on the data, the algal growth in the lake appears to be phosphorus-limited. The average summer total phosphorus concentration (i.e., 0.031 mg/L) from the epilimnion (i.e., surface waters) of Little Ripley Lake was within the eutrophic (i.e., nutrient-rich) category, indicating the lake has the potential for problematic algal blooms throughout the summer period. The lake's average summer chlorophyll *a* concentration (i.e., 42.9 μg/L) from the epilimnion was within the eutrophic (i.e., highly productive) category, indicating undesirable algal blooms occur during the summer period. The average summer Secchi disc measurement (i.e., 1.3 meters) was within the eutrophic category, indicating moderate recreational-use impairment occurred during the summer period.

The watershed tributary to Little Ripley Lake is approximately 400 acres or approximately 8 times the surface area of the lake (i.e., approximately 47 acres). The lake's watershed is largely undeveloped (i.e., 86 percent) and is primarily comprised of forestland (64 percent). Watershed areas affected by development include agricultural land (i.e., less than 5 percent) and open space areas, including residential areas (i.e., approximately 11.5 percent).

Uncontrolled development of the lake's watershed would likely result in significant degradation of the lake's water quality. Development of a management plan for Little Ripley Lake and its watershed is recommended to preserve the lake's current water quality.

Little Ripley Lake Management Plan
Phase I: Water Quality Study of Little Ripley Lake

Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 Introduction

Little Ripley Lake is located in Washburn County, Wisconsin (T37N, R12W, Secs. 5, 8, 9). The lake is a seepage lake located within the Shell Lake Inland Lake Protection and Rehabilitation District. It notes a surface area of 47.3 acres and a maximum depth of 14 feet. The lake notes dark brown stained water and an abundance of vegetation. The lake's fishery is comprised of largemouth bass and bluegills. The lake is subject to occasional partial winterkill conditions. The lake is elongated east and west and has a steep sloping and irregular shoreline. Upland hardwoods surround the entire lake.

During 1997 the Shell Lake Inland Protection and Rehabilitation District completed a water quality study of the lake. This report discusses the methodology, results, and the recommendations from the water quality study. The report will answer the following two questions that apply to properly managing lakes:

1. What is the general condition of the lake?
2. Are there water quality problems?

To answer the first question, the report begins with a description of methods of data collection and analysis. The results of the water quality monitoring are then summarized in tables, figures, and accompanying descriptions. To answer the second question, data are analyzed and compared to established water quality standards for lakes.

A third and final question will be answered in intended subsequent projects to develop a lake management plan.

3. Can the lake's water quality be protected from degradation by controlling future development and/or implementation of management practices to reduce phosphorus loads to the lake?

A background section is also included in the report. Section 3.0 covers general concepts in lake water quality.

2.0 Methods

2.1 Lake Water Quality Data Collection

In 1997, a representative lake sampling station was selected for Little Ripley Lake (i.e., at the deepest location in the lake, see Figure 1). Water chemistry and biological samples were collected during the spring and summer period. Spring samples were collected because average summer conditions are related to conditions immediately following spring overturn of the lake. Collection of summer samples was scheduled to span the lake's period of elevated biological activity. Samples collected included:

- Nutrient samples (i.e., phosphorus and nitrogen species) and chlorophyll *a* samples were collected at spring overturn (shortly after ice-out) and five times during the summer period (June through early-September).
- Phytoplankton samples were collected during spring and on three occasions during the summer period (i.e., twice during July and once during early-September).
- Zooplankton samples were collected on three occasions during the summer period (i.e., twice during July and once during early-September).
- Alkalinity and pH samples were collected on one occasion. A volunteer intended to collect the samples on two occasions as outlined in the project work scope, but collected the samples on only one occasion.

Field parameters were measured monthly during April through June, twice during July, and monthly during August through September. A less frequent field measurement schedule was followed by volunteers than the intended schedule outlined in the project work scope. The intended schedule of measurement was once every two weeks during the April through October period, once during early-winter, and once during late-winter.

Table 1 lists the 12 water quality parameters measured at each station, and specifies at what depths samples or measurements were collected. Dissolved oxygen, temperature, specific conductance, and Secchi disc transparency were measured in the field; whereas, water samples were analyzed in the laboratory for total phosphorus, soluble reactive phosphorus, total Kjeldahl nitrogen, ammonia nitrogen, nitrate plus nitrite nitrogen, chlorophyll *a,* pH, alkalinity, phytoplankton, and zooplankton. Samples and measurements were collected by Shell Lake Inland Lake Protection and Rehabilitation District volunteers.

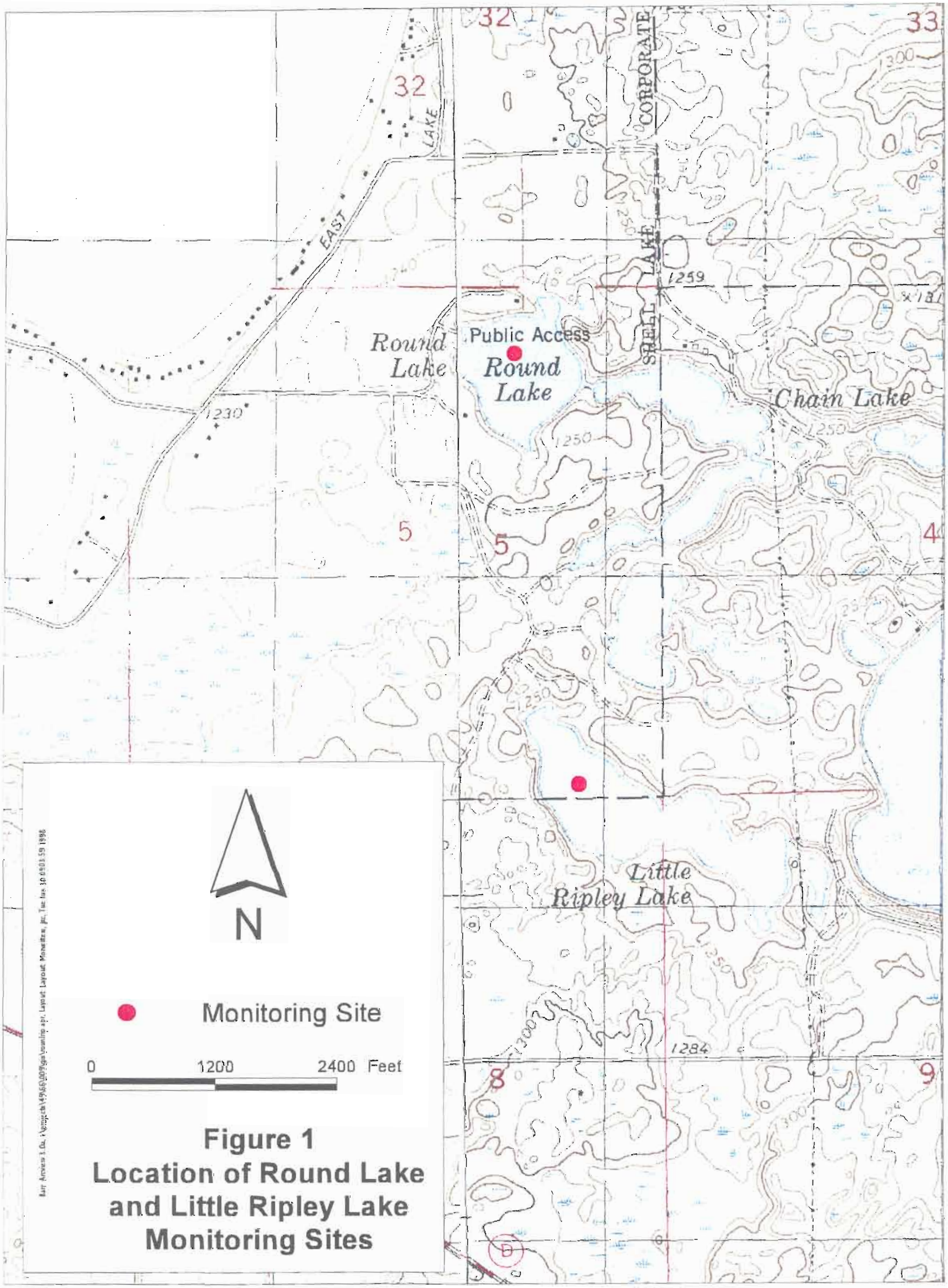


Figure 1
Location of Round Lake and Little Ripley Lake Monitoring Sites

Table 1 **Little Ripley Lake Water Quality Parameters**

Parameters	Depth (meters)
Dissolved Oxygen	Surface to bottom profile
Temperature	Surface to bottom profile
Specific Conductance	Surface to bottom profile
pH	0-2
Chlorophyll *a*	0-2
Secchi Disc	—
Total Phosphorus	0-2 and near bottom (i.e., one-half meter above the lake bottom)
Soluble Reactive Phosphorus	0-2
Total Kjeldahl, Ammonia, and Nitrate + Nitrite Nitrogen	0-2
Alkalinity	0-2
Phytoplankton	0-2
Zooplankton	Bottom to surface tow

2.2 Lake Level Monitoring

A lake level staff gage was installed during April and a volunteer intended to read the gage on a daily basis. However, the actual measurements include one measurement during the spring period (i.e., a value of 2.4 feet, no date given) and a measurement of 1.7 feet on November 3, 1997.

2.3 Precipitation Monitoring

Precipitation data were collected by city of Shell Lake staff during the period January through October. The gage location was the City Shop in Shell Lake, Wisconsin. Measurements are presented in Appendix B. The information was collected for the intended use of completion of the lake's hydrologic budget in a subsequent project.

2.4 Evaluation of the Tributary Watershed

The United States Department of Agriculture Natural Resources Conservation Service in Spooner, Wisconsin provided watershed, soils, and land use information for the Little Ripley watershed.

3.0 General Concepts in Lake Water Quality

There are many concepts and terminology that are necessary to describe and evaluate a lake's water quality. This section is a brief discussion of those concepts, divided into the following topics:

- Eutrophication
- Trophic states
- Limiting-nutrients
- Nutrient recycling and internal loading
- Stratification
- Lake Zones
- Riparian Zone
- Watershed

To learn more about these five topics, one can refer to any text on limnology (the science of lakes and streams).

3.1 Eutrophication

Eutrophication, or lake degradation, is the accumulation of sediments and nutrients in lakes. As a lake naturally becomes more fertile, algae and weed growth increases. The increasing biological production and sediment inflow from the lake's watershed eventually fill the lake's basin. Over a period of many years, the lake successively becomes a pond, a marsh and, ultimately, a terrestrial site. This process of eutrophication is natural and results from the normal environmental forces that influence a lake. Cultural eutrophication, however, is an acceleration of the natural process caused by human activities. Nutrient and sediment inputs (i.e., loadings) from wastewater treatment plants, septic tanks, and stormwater runoff can far exceed the natural inputs to the lake. The accelerated rate of water quality degradation caused by these pollutants results in unpleasant consequences. These include profuse and unsightly growths of algae (algal blooms) and/or the proliferation of rooted aquatic weeds (macrophytes).

3.2 Trophic States

Not all lakes are at the same stage of eutrophication; therefore, criteria have been established to evaluate the nutrient "status" of lakes. Trophic state indices (TSIs) are calculated for lakes on the basis of total phosphorus, chlorophyll *a* concentrations, and Secchi disc transparencies. A TSI value is obtained from any one of these three parameters. TSI values range upward from zero, describing the condition of the lake in terms of its trophic status (i.e., its degree of fertility). Four trophic status designations for lakes are listed below with corresponding TSI value ranges:

1. ***Oligotrophic* – [TSI ≤ 37]** Clear, low productivity lakes with total phosphorus concentrations less than or equal to 10 µg/L.
2. ***Mesotrophic* – [38 ≤ TSI ≤ 50]** Intermediate productivity lakes with total phosphorus concentrations greater than 10 µg/L, but less than 25 µg/L.
3. ***Eutrophic* – [51 ≤ TSI ≤ 63]** High productivity lakes generally having 25 to 57 µg/L total phosphorus.
4. ***Hypereutrophic* – [64 ≤ TSI]** Extremely productive lakes that are highly eutrophic, disturbed and unstable (i.e., fluctuating in their water quality on a daily and seasonal scale, producing gases, off-flavor, and toxic substances, experiencing periodic anoxia and fish kills, etc.) with total phosphorus concentrations above 57 µg/L.

Determining the trophic status of a lake is an important step in diagnosing water quality problems. Trophic status indicates the severity of a lake's algal growth problems and the degree of change needed to meet its recreational goals. Additional information, however, is needed to determine the cause of algal growth and a means of reducing it.

3.3 Limiting-Nutrients

The quantity or biomass of algae in a lake is usually limited by the water's concentration of an essential element or nutrient—the "limiting-nutrient." (For rooted aquatic plants, most nutrients are derived from the sediments.) The limiting-nutrient concept is a widely applied principle in ecology and in the study of eutrophication. It is based on the idea that plants require many nutrients to grow, but the nutrient with the lowest availability, relative to the amount needed by the plant, will limit plant growth. It follows then, that identifying the limiting-nutrient will point the way to controlling algal growth.

Nitrogen (N) and phosphorus (P) are generally the two growth-limiting nutrients for algae in most natural waters. Analysis of the nutrient content of lake water and algae provides ratios of N:P. By comparing the ratio in water to the ratio in the algae, one can estimate whether a particular nutrient may be limiting. Algal growth is generally phosphorus-limited in waters with N:P ratios greater than 12. Laboratory experiments (bioassays) can demonstrate which nutrient is limiting by growing the algae in lake water with various concentrations of nutrients added. Bioassays, as well as fertilization of in-situ enclosures and whole-lake experiments, have repeatedly demonstrated that phosphorus is usually the nutrient that limits algal growth in fresh waters. Reducing phosphorus in a lake, therefore, is required to reduce algal abundance and improve water transparency. Failure to reduce phosphorus concentrations will allow the process of eutrophication to continue at an accelerated rate.

3.4 Nutrient Recycling and Internal Loading

Phosphorus enters a lake from either runoff from the watershed or direct atmospheric deposition. It would, therefore, seem reasonable that phosphorus in a lake can decrease by reducing these external loads of phosphorus to the lake. All lakes, however, accumulate phosphorus (and other nutrients) in the sediments from the settling of particles and dead organisms. In some lakes this reservoir of phosphorus can be reintroduced in the lake water and become available again for plant uptake. This resuspension or dissolution of nutrients from the sediments to the lake water is known as "internal loading." The relative amounts of phosphorus coming from internal and external loads vary with each lake. Phosphorus released from internal loading can be estimated from depth profiles (measurements from surface to bottom) of dissolved oxygen and phosphorus concentrations.

3.5 Stratification

The process of internal loading is dependent on the amount of organic material in the sediments and the depth-temperature pattern, or "thermal stratification," of a lake. Thermal stratification profoundly influences a lake's chemistry and biology. When the ice melts and air temperature warms in spring, lakes generally progress from being completely mixed to stratified with only an upper warm well-mixed layer of water (epilimnion), and cold temperatures in a bottom layer (hypolimnion). Because of the density differences between the lighter warm water and the heavier cold water, stratification in a lake can become very resistant to mixing. When this occurs, generally in mid-summer, oxygen from the air cannot reach the bottom lake water and, if the lake sediments have sufficient organic matter, biological activity can deplete the remaining oxygen in the hypolimnion. The epilimnion can remain well-oxygenated, while the water above the sediments in the hypolimnion becomes completely devoid of dissolved oxygen (anoxic). Complete loss of oxygen changes the chemical conditions in the water and allows phosphorus that had remained bound to the sediments to reenter the lake water.

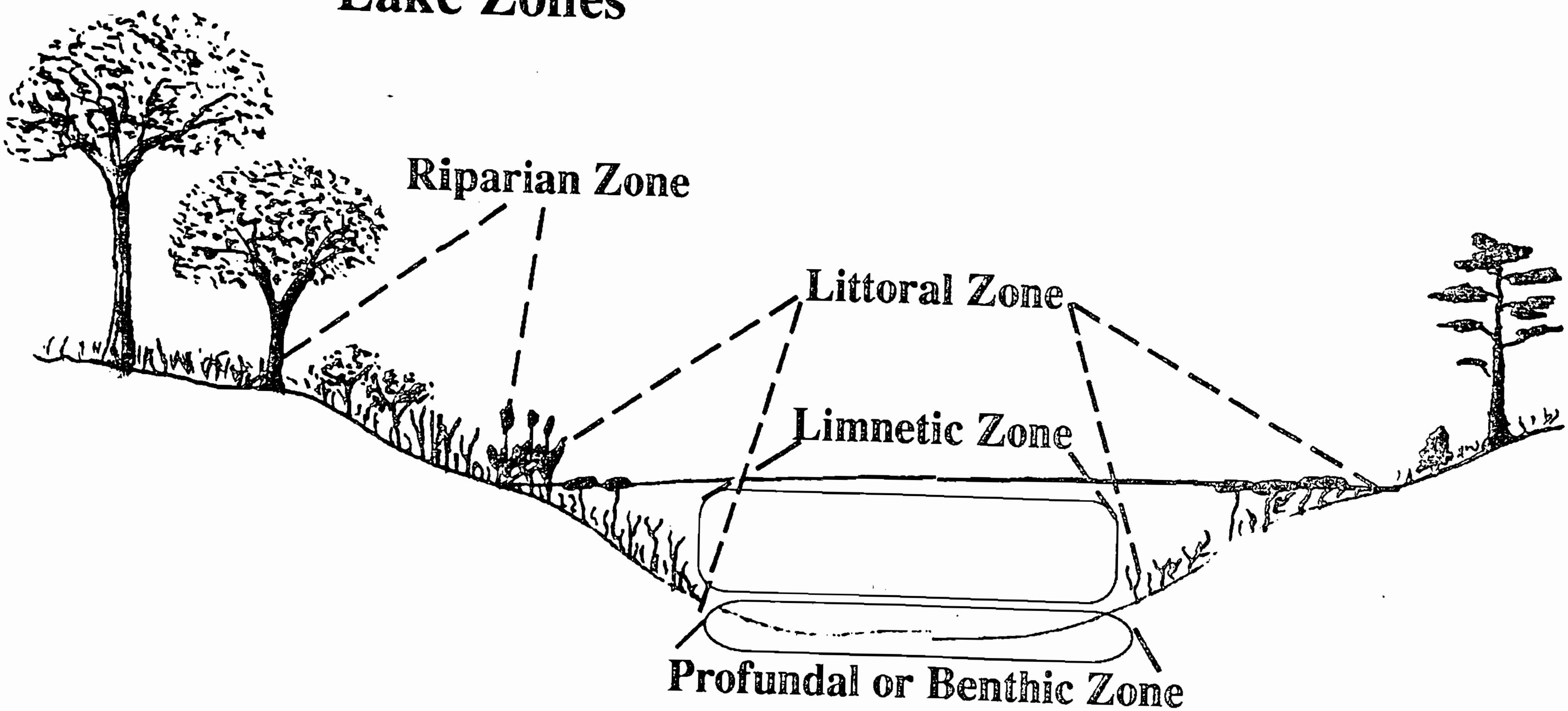
As the summer progresses, phosphorus concentrations in the hypolimnion can continue to rise until oxygen is again introduced (recycled). Dissolved oxygen concentration will increase if the lake sufficiently mixes to disrupt the thermal stratification. Phosphorus in the hypolimnion is generally not available for plant uptake because there is not sufficient light penetration to the hypolimnion to allow for growth of algae. The phosphorus, therefore, remains trapped and unavailable to the plants until the lake is completely mixed. In shallow lakes this can occur throughout the summer, with sufficient wind energy (polymixis). In deeper lakes, however, only extremely high wind energy is sufficient to destratify a lake during the summer and complete mixing only occurs in the spring and fall (dimixis). Cooling air temperature in the fall reduces the epilimnion water temperature, and consequently increases the density of water in the epilimnion. As the epilimnion water density approaches the density of the hypolimnion water very little energy is needed to cause complete mixing of the lake. When this fall mixing occurs, phosphorus that has built up in the hypolimnion is mixed with the epilimnion water and becomes available for plant growth.

3.6 Lake Zones

Lakes are not homogenous, but are rather comprised of several different habitats for aquatic life. Each type of habitat or lake zone impacts the overall health of the lake. Lake zones (See Figure 2) include:

- **Littoral Zone**—The shallow transition zone between dry land and the open water area of the lake is the littoral zone. The shallow water, abundant light, and nutrient-rich sediment provide ideal conditions for plant growth. Aquatic plants, in turn, provide food and habitat for many animals such as fish, frogs, birds, muskrats, turtles, insects, and snails. Lakes with clearer water may have aquatic plants growing at greater depths than lakes with poor water clarity. As a result, the littoral zone may vary depending on the lake's water clarity as well as its depths.

Lake Zones



Source: The Lakes of Barron County: A Report on their Status in 1996

Figure 2

- **Profundal Zone**—the bottom zone in the deeper areas of the lake (i.e., in water deeper than the littoral zone). Deposition and decomposition of organic material occurs in this zone. This area often lacks oxygen because decomposition uses up available oxygen. A related term is benthic zone.

- **Limnetic Zone**—the open water area of the lake in water deeper than the littoral zone. It is located from the lake's surface to the depth at which the profundal zone begins. This zone is inhabited by phytoplankton, zooplankton, and/or fish. The microscopic algae or phytoplankton provide the foundation of the food pyramid of the lake. The zooplankton (i.e., small animals) feed upon the phytoplankton and provide a food source for higher life forms such as fish.

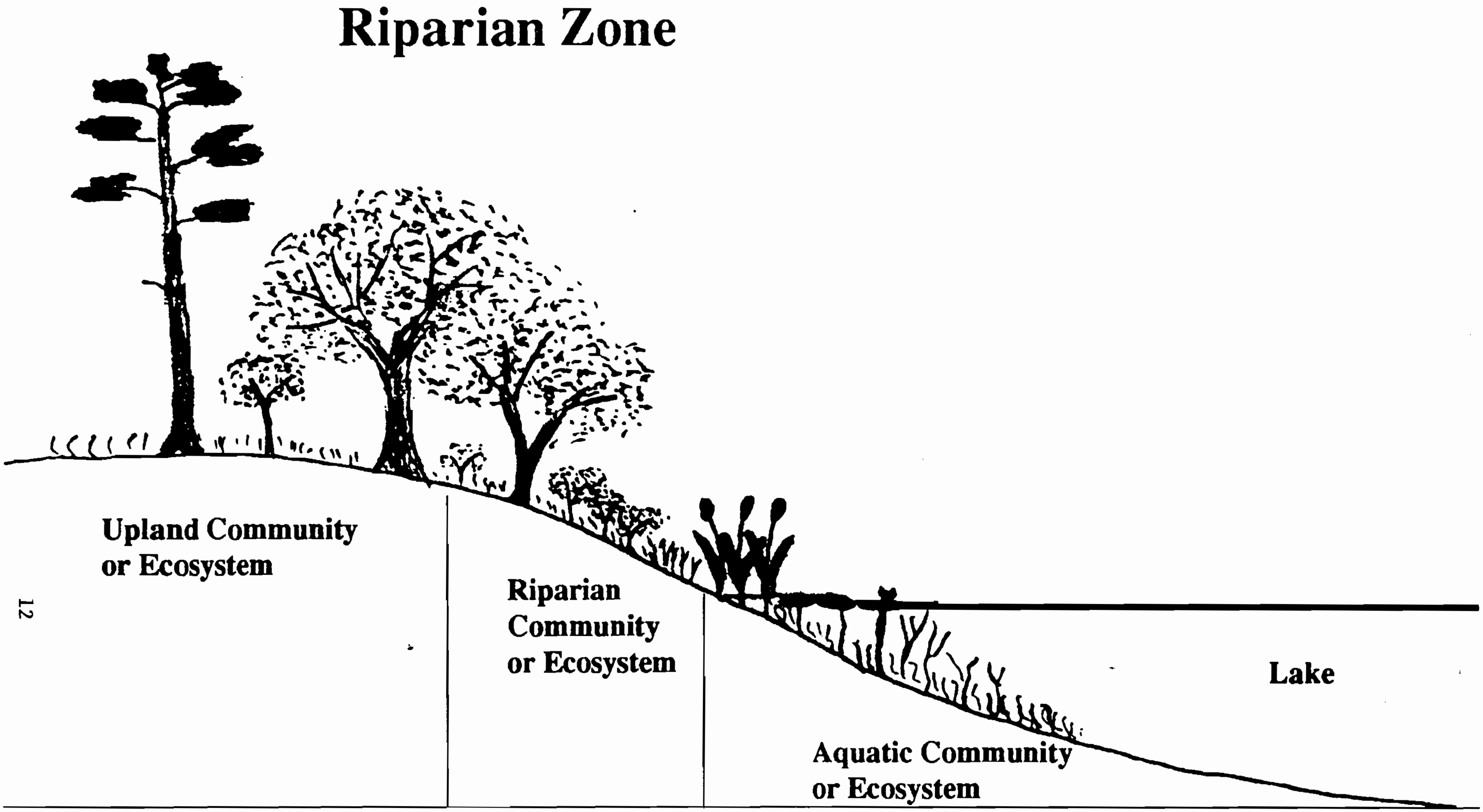
Each of the lake zones is important for lake health. None can be neglected or negatively impacted without influencing the entire lake ecosystem.

3.7 Riparian Zone

Riparian zones (see Figure 3) are extremely important to the lake and to the plants living there. Riparian vegetation is that growing close to the lake and may be different from the terrestrial or upland vegetation. The width of the riparian zone varies depending on many variables, including soils, vegetation, slopes, soil moisture, water table, and even by location on the lake. For example, north shore vegetation may provide little or no shade, while vegetation on the southern shore may offer shade and cover well into the lake.

The riparian area and riparian vegetation is important for several reasons:

- Acts as a filter from outside impacts.
- Stabilizes the bank with an extensive root system.
- Helps control or filter erosion
- Provides screening to protect visual quality and hides man's activities and buildings.
- Provides the natural visual backdrop as seen from the lake.
- Provides organic material to the lake's food web. Leaves, needles, and woody debris are fed upon by bacteria, fungi, and aquatic insects. This energy flows upward through the food web.
- Offers cover and shade for fish and other aquatic life.
- Provides valuable wildlife habitat



Source: The Lakes of Barron County:
A Report on their Status in 1996

Figure 3

Riparian zones are the areas most often impacted, and riparian vegetation is lost when man enters the picture. Cabins, homes, lawns, and boat houses replace riparian vegetation. Additional riparian vegetation is eliminated to provide a wider vista from the front deck, or it is mowed and its value to the lake is lost.

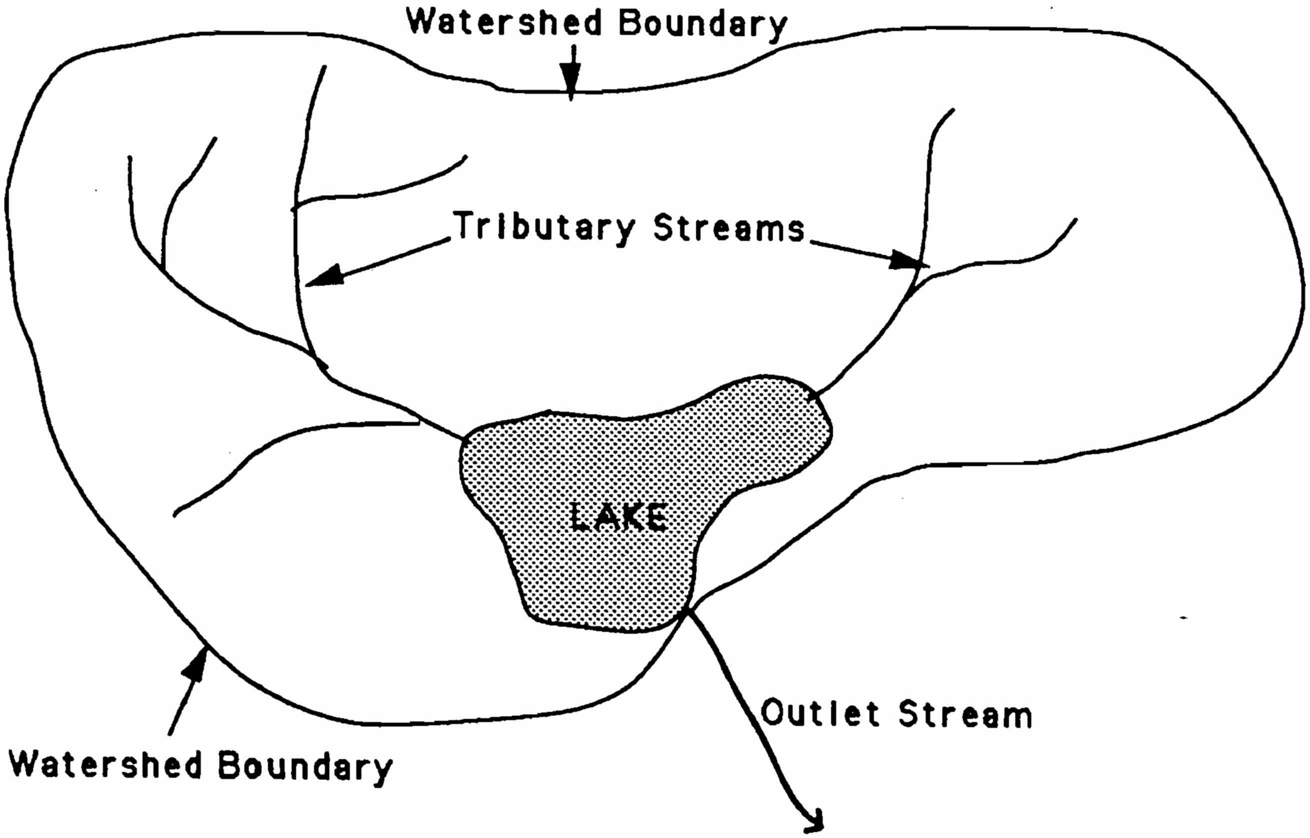
The loss of riparian vegetation results in deterioration of many lake values. Water quality is impacted, wildlife habitat is lost, scenic quality suffers, fish habitat may be impacted, bank stability is weakened, and the potential for erosion increases. Riparian vegetation filters phosphorus from runoff waters, thereby protecting the lake's water quality. The loss of riparian vegetation results in increased phosphorus loads to the lake, which causes water quality degradation.

3.8 Watershed

The land area that drains to the lake is called a watershed (See Figure 4). The watershed may be small, as is the case of small seepage lakes such as Little Ripley Lake (i.e., Seepage lakes have no stream inlet or outlet. The lake's watershed includes the land draining directly to the lake); or large, as in drainage lakes (i.e., Drainage lakes have both stream inlets and outlets. The lake's watershed includes the land draining to the streams besides the land draining directly to the lake). Water draining to a lake may carry pollutants that affect the lake's water quality. Consequently, water quality conditions of the lake are a direct result of the land use practices within the watershed. Poor water quality may reflect poor land use practices or pollution problems within the watershed. Good water quality conditions suggest that proper land uses are occurring in the watershed.

All land use practices within a lake's watershed impact the lake and determine its water quality. Impacts result from the export of sediment and nutrients, primarily phosphorus, to a lake from its watershed. Each land use contributes a different quantity of phosphorus to the lake, thereby, affecting the lake's water quality differently. An understanding of a lake's water quality, therefore, must go beyond an analysis of the lake itself. An understanding of a lake's watershed, phosphorus exported from the watershed, and the relationship between the lake's water quality and its watershed must be understood.

Watershed Map of a Lake



Source: The Lakes of Barron County:
A Report on their Status in 1996

Figure 4

4.0 Results and Discussion

4.1 Phosphorus

Phosphorus is the plant nutrient that most often limits the growth of algae. Phosphorus-rich lake water indicates a lake has the potential for abundant algal growth, which can lead to lower water transparency and a decline in hypolimnetic oxygen levels in a lake.

Algal growth is generally phosphorus-limited in waters with nitrogen (N) to phosphorus (P) ratios greater than 12. To determine the nutrient-limiting algal growth in Little Ripley Lake, N:P ratios for Little Ripley Lake were evaluated and the average N:P ratio determined (i.e., 23.7). Based on the data presented in Table 2, Little Ripley Lake appears to be phosphorus-limited.

Table 2 **1997 Little Ripley Lake Surface Water April through September N:P Ratios**

Date	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	N:P Ratio
4/28	0.80	0.046	17.4
6/24	0.79	0.030	26.3
7/8	0.70	0.024	29.2
9/02	1.00	0.046	21.7
		Average N:P	**23.7**

Total phosphorus data collected from the epilimnion (i.e., surface waters) of Little Ripley Lake during 1997 were generally within the eutrophic (i.e., nutrient-rich) category. Data collected during July, however, were on the borderline for the eutrophic/mesotrophic categories (See Figure 5). The average summer phosphorus concentration was within the eutrophic category, indicating the lake has the potential for problematic algal blooms throughout the summer period.

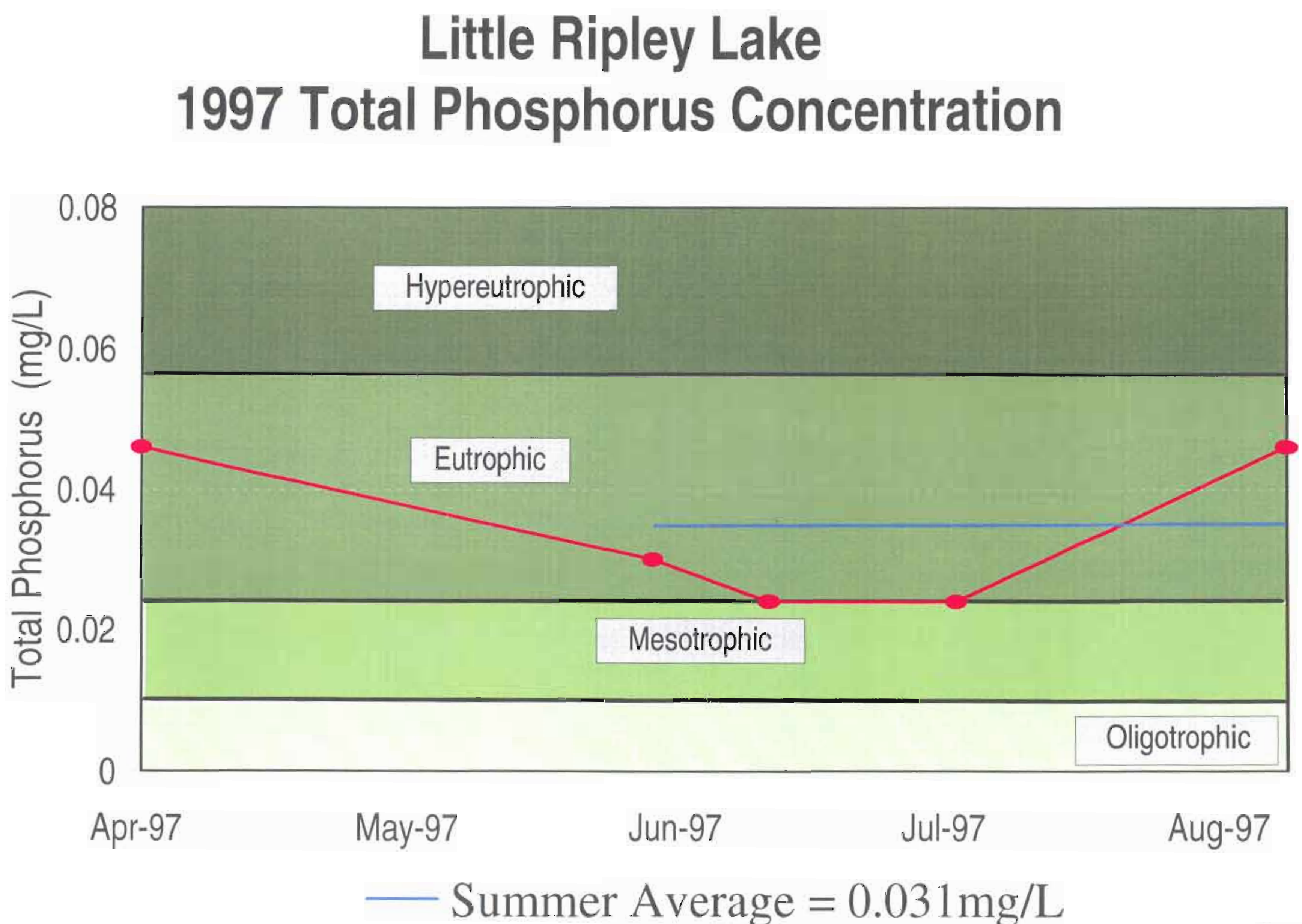

Little Ripley Lake
1997 Total Phosphorus Concentration
Total Phosphorus (mg/L)
0.08
0.06
0.04
0.02
0
Hypereutrophic
Eutrophic
Mesotrophic
Oligotrophic
Apr-97
May-97
Jun-97
Jul-97
Aug-97
Summer Average = 0.031mg/L

Figure 5

4.2 Chlorophyll *a*

Chlorophyll a is a measure of algal abundance within a lake. High chlorophyll a concentrations indicate excessive algal abundance (i.e., algal blooms), which can lead to recreational use impairment.

The 1997 Little Ripley Lake chlorophyll *a* data indicate the lake's average summer chlorophyll concentration was within the eutrophic (i.e., highly productive) category (See Figure 6). The data indicate undesirable algal blooms occur during the summer period. Concentrations on individual sample dates included values in the eutrophic (i.e., highly productive) category during April and July and values in the hypereutrophic (i.e., very highly productive) category during June and August. The seasonal pattern of chlorophyll *a* concentrations was similar to phosphorus concentrations suggesting that the lake's algal growth is directly related to phosphorus levels. The chlorophyll data indicate a relatively high algal yield resulted from the lake's available phosphorus.

4.3 Secchi Disc Transparency

Secchi disc transparency is a measure of water clarity. Perceptions and expectations of people using a lake are generally correlated with water clarity. Results of a survey completed by the Metropolitan Council (Osgood, 1989) revealed the following relationship between a lake's recreational use impairment and Secchi disc transparencies:

- *No impairment occurs at Secchi disc transparencies greater than 4 meters (13 feet).*
- *Minimal impairment occurs at Secchi disc transparencies of 2 to 4 meters (7 to 13 feet).*
- *Moderate impairment occurs at Secchi disc transparencies of 1 to 2 meters (3 to 7 feet).*
- *Moderate to severe use-impairment occurs at Secchi disc transparencies less than 1 meter (3 feet).*

Secchi disc measurements in Little Ripley Lake were generally within the eutrophic category (i.e., transparency from 0.85 to 2 meters). The seasonal patterns suggest the lake's water transparency is largely determined by algal abundance. The summer average Secchi disc measurement (i.e., 1.3 meters) was within the eutrophic category, indicating moderate recreational use impairment occurred in Little Ripley Lake (See Figure 7).

Ripley Lk:1997 Epilimnetic Chlorophyll Concentration

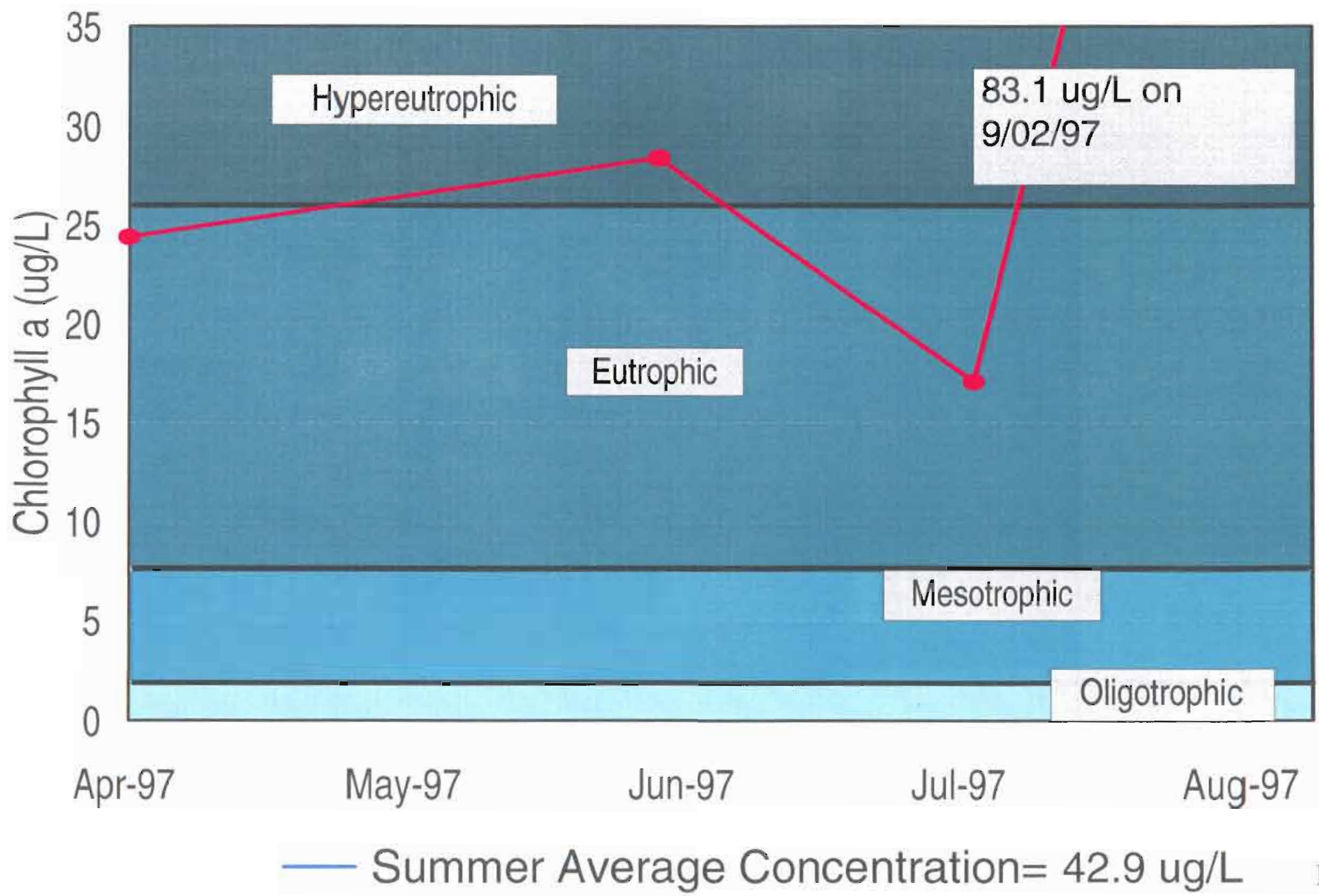
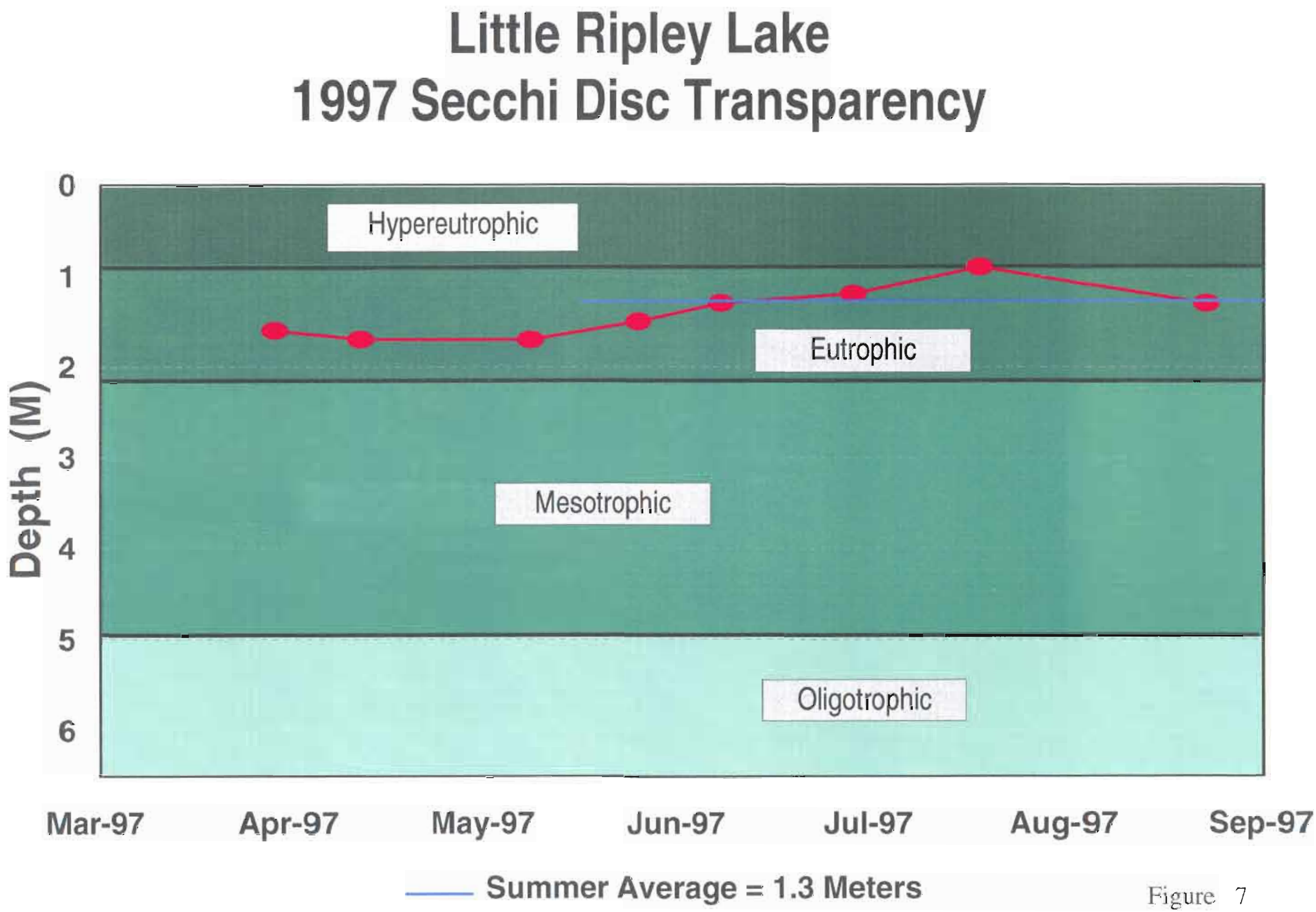


Figure 6



Little Ripley Lake
1997 Secchi Disc Transparency
Depth (M)
0
1
2
3
4
5
6
Hypereutrophic
Eutrophic
Mesotrophic
Oligotrophic
Mar-97
Apr-97
May-97
Jun-97
Jul-97
Aug-97
Sep-97
Summer Average = 1.3 Meters

Figure 7

4.4 Temperature, Dissolved Oxygen, and Specific Conductance Isopleth Diagrams

Isopleth diagrams represent the change in a parameter relative to depth and time. For a given time period, vertical isopleths indicate complete mixing and horizontal isopleths indicate stratification.

Isopleth diagrams are useful for showing patterns with depth and time when sufficient depth profile data are available. Isopleth diagrams of temperature, dissolved oxygen, and specific conductance were prepared for Little Ripley Lake. The temperature isopleth diagram (See Figure 8) indicates the lake was mixed completely during the spring (i.e., same temperature from surface to lake bottom) and exhibited weak stratification throughout the summer period (i.e., temperature layers from surface to lake bottom). The dissolved oxygen isopleth diagram (See Figure 9) shows that the lake was well oxygenated from surface to near the bottom throughout the measurement period. A dissolved oxygen concentration of 5.0 mg/L is considered the minimum desirable level for fish. Oxygen concentrations below 5.0 mg/L were observed in the near bottom waters (i.e., within 0.5 to 1 meter of the lake's bottom) during July through September. All other portions of the lake contained oxygen concentrations greater than 5.0 mg/L throughout the measurement period. Therefore, fish were able to inhabit the entire lake during the April through June period and all but the lake's near bottom waters during the July through September period.

Specific conductance is directly related to the amount of dissolved inorganic chemicals (minerals, nutrients, metals, and other inorganic chemicals) in the water. Specific conductance levels are a reflection of the soils and bedrock in the lake's watershed. They also indicate the level of internal loading (i.e., the resuspension of phosphorus from the sediments to the lake water). A relatively low specific conductance level occurred in Little Ripley Lake throughout the monitoring period (See Figure 10).

Temperature Isopleth (degrees C)
Little Ripley Lake Wisconsin

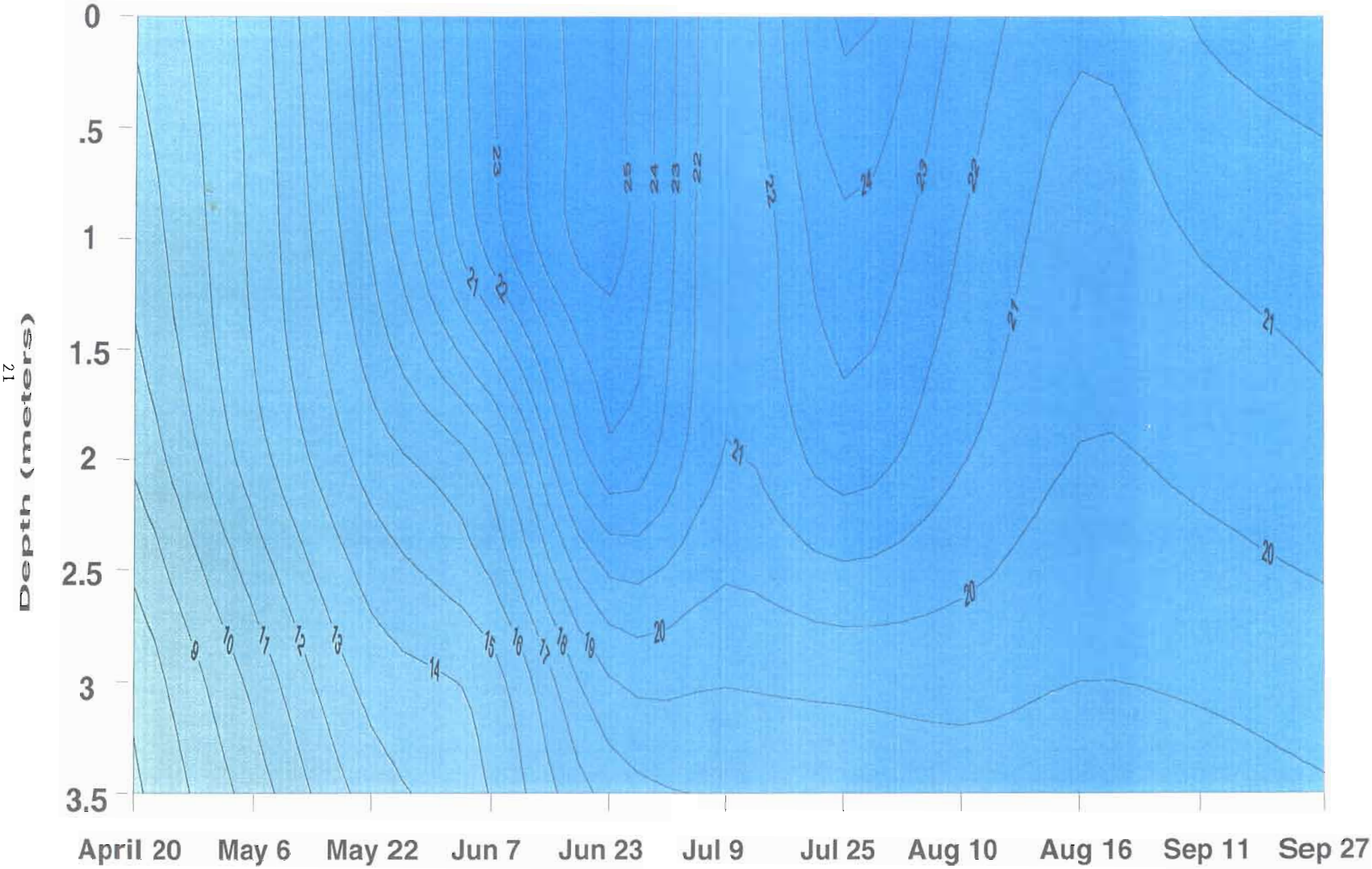


Figure 8

Dissolved Oxygen Isopleth (mg/L)
Little Ripley Lake Wisconsin

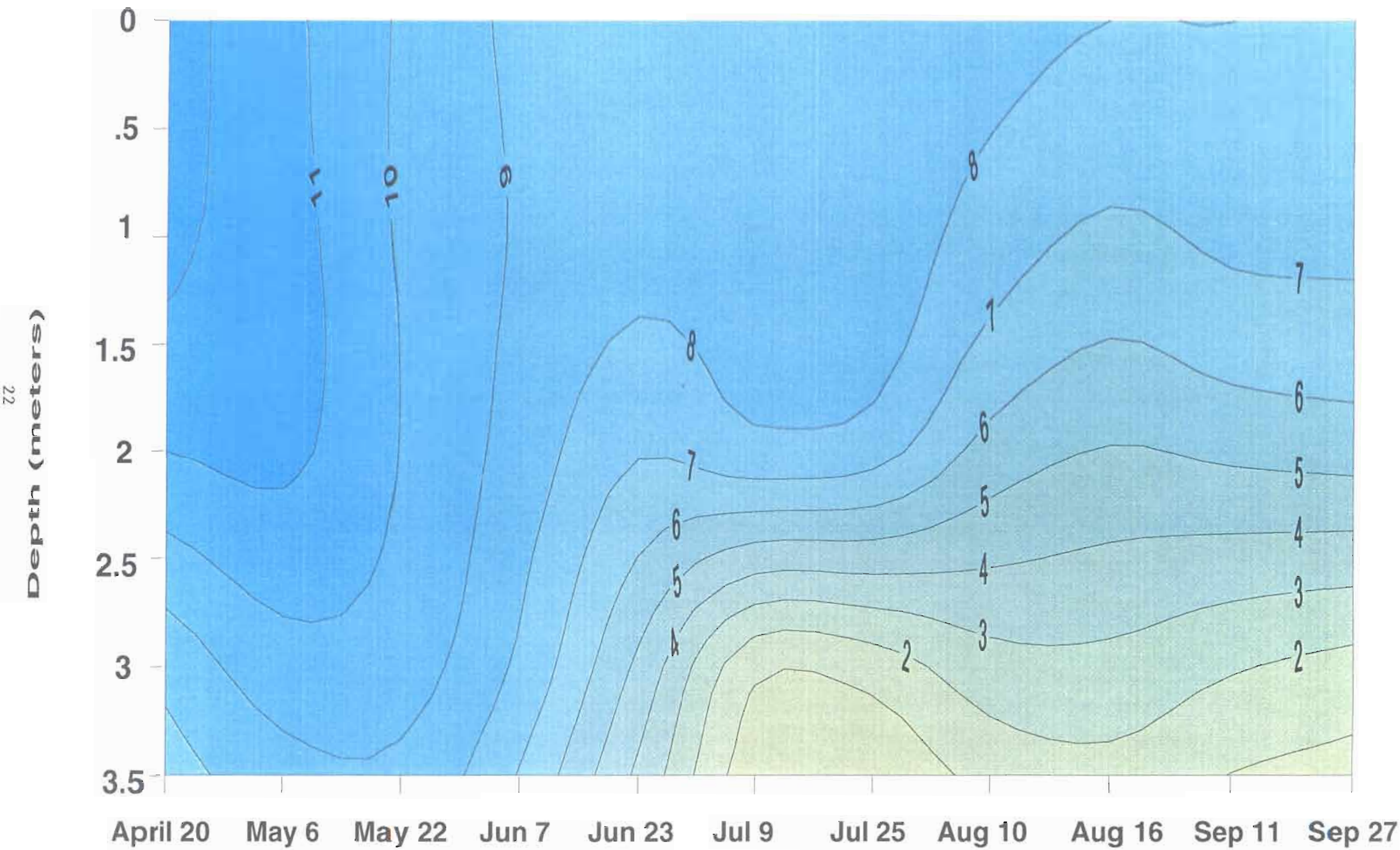


Figure 9

Conductivity Isopleth (umhos/cm)
Little Ripley Lake Wisconsin

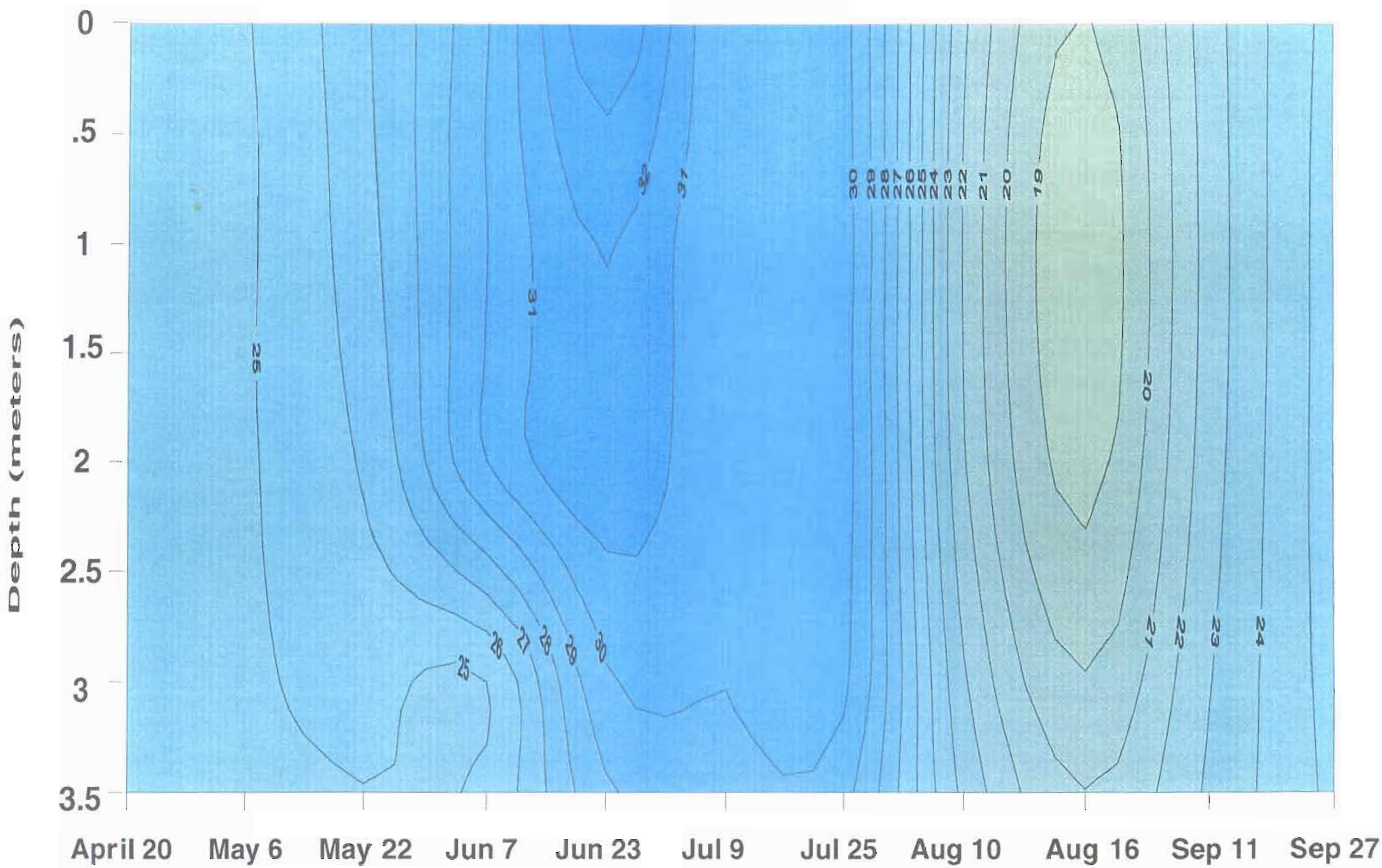


Figure 10

4.5 Phytoplankton

Phytoplankton, also called algae, are small aquatic animals, naturally present in all lakes. They derive energy from sunlight (through photosynthesis) and from dissolved nutrients found in lake water. They provide food for several types of animals, including zooplankton, which are eaten by fish. A phytoplankton population in balance with the lake's zooplankton population is ideal for fish production. An inadequate phytoplankton population reduces the lake's zooplankton population and adversely impacts the lake's fishery. Excess phytoplankton, however, can interfere with the recreational usage of a lake and is considered problematic.

The phytoplankton population of Little Ripley Lake consisted of a diverse assemblage representing green algae, blue-green algae, golden-brown algae, diatoms, cryptomonads, and dinoflagellates (See Figure 11). The community was dominated by *Chlamydomonas globosa* (a green alga) throughout the sample period. During the summer period, several blue-green species (i.e., *Microcystis incerta, Aphanizomenon flos-aquae,* and *Anabaena affinis*) were also abundant. The cryptomonad, *Cryptomonas erosa*, was abundant during September. The numbers of algal cells increased throughout the summer period, thus, corroborating the chlorophyll *a* data. With the exception of the blue-green species, the Little Ripley algal community provides food for the aquatic community and is a vital link in the lake's fishery.

Little Ripley Lake Phytoplankton (Total Number by Taxa)

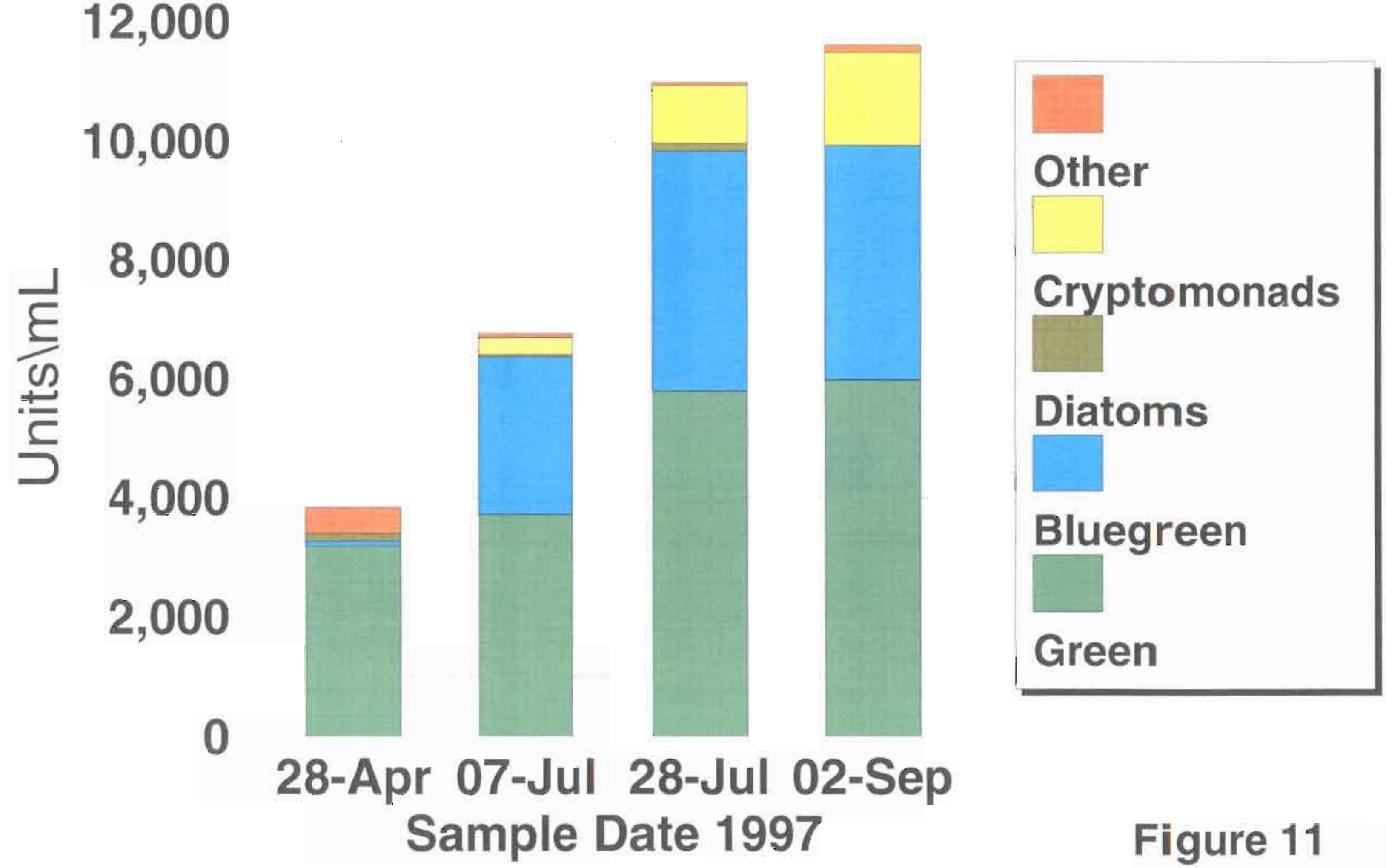


Figure 11

4.6 Zooplankton

Zooplankton are microscopic aquatic animals which feed on particulate plant matter, including algae, and are in turn eaten by fish. Protection of a lake's zooplankton community through judicious management practices affords protection to the lake's fishery.

Two types of zooplankton were found in Little Ripley Lake during 1997, rotifers and copepods. Rotifers were dominant throughout the monitoring period, comprising from 67 percent to 92 percent of the zooplankton community (See Figure 12).

The zooplankton community in Little Ripley Lake provides food for the lake's fishery, but has little predatory impact on the lake's algal community. This is primarily due to the absence of cladocera in the lake. The rotifers and copepods in Little Ripley Lake graze primarily on extremely small particles of plant matter, and do not significantly affect the lake's water quality. However, the cladocera graze primarily on algae. If present in abundance, large cladocera can decrease the number of algae and improve water transparency within a lake.

The abundance of cladocera in a lake is dependent upon their ability to escape predation by predatory fish. Planktivorous fish, such as sunfish and perch, feed readily on large cladocera. Cladocera are slow swimmers. Daphnids, for example, travel at a rate of 6 centimeters per second (2.4 inches per second) (Cushing 1955). Copepods, especially diaptomid copepods, have been found to be rapid swimmers. *Cyclops scutifer* moves at a rate of 30 to 50 centimeters per second (11.8 to 19.7 inches per second) (Strickler 1975) and *Diaptomus kenai* at a rate of 145 centimeters per second (57.1 inches per second) (Swift and Fedorenko 1975). Copepods are much more likely to avoid predation than cladocera. The absence of cladocera in Little Ripley Lake suggests the removal of cladocera by planktivorous fish.

The lake's dominance by rotifers throughout the monitoring period is believed to be due to their small size relative to cladocera and copepoda. Fish feed by sight and select the largest zooplankters available to them. Consequently, rotifers are only selected when larger choices (i.e., cladocera and copepods) are unavailable. The lake's dominance by rotifers indicates planktivorous fish have removed the majority of the larger types of zooplankton (i.e., cladocera and copepods).

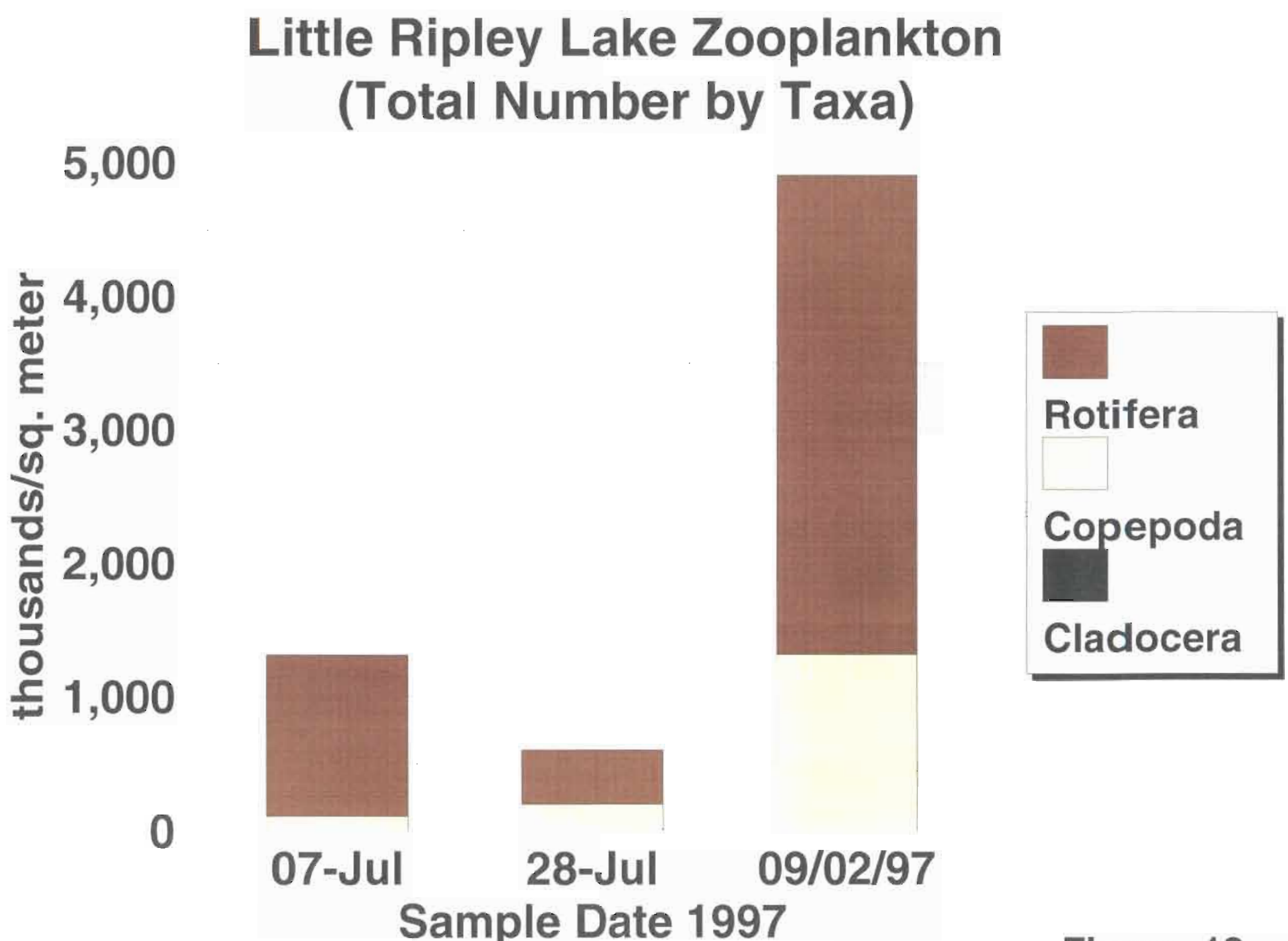


Figure 12

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The presence of a zooplankton refuge within a lake provides a means of escape from predation by planktivorous fish for zooplankton. Little Ripley Lake is a shallow lake and lacks the depth required for a refuge. Consequently, planktivorous fish prey upon zooplankton throughout the lake. The data suggest lake-wide fish predation results in nondetectable levels of cladocera and relatively low levels of copepods in the lake. The bathymetry (i.e., depth patterns) of the lake suggests the zooplankton community observed in Little Ripley Lake is a natural condition of the lake.

4.7 Watershed Evaluation

The land area that drains to a lake is called its watershed. All land use practices within a lake's watershed impact the lake and determine its water quality. Impacts result from the export of sediment and nutrients, primarily phosphorus, to a lake from its watershed.

The watershed tributary to Little Ripley Lake is approximately 400 acres (i.e., including the lake's surface area of approximately 47 acres) (See Figure 13). Little Ripley Lake notes a ratio of watershed area to lake surface area of 8 to 1. The lake's watershed is largely undeveloped (i.e., approximately 86 percent) and primarily consists of forestland (i.e., 64 percent) (See Figure 14). Open space areas, including residential areas, comprise approximately 11.5 percent of the lake's watershed. Agricultural land use comprises less than 5 percent of the lake's watershed. Approximately 11 acres of agricultural land in the Little Ripley watershed is Highly Erodible Land (HEL).

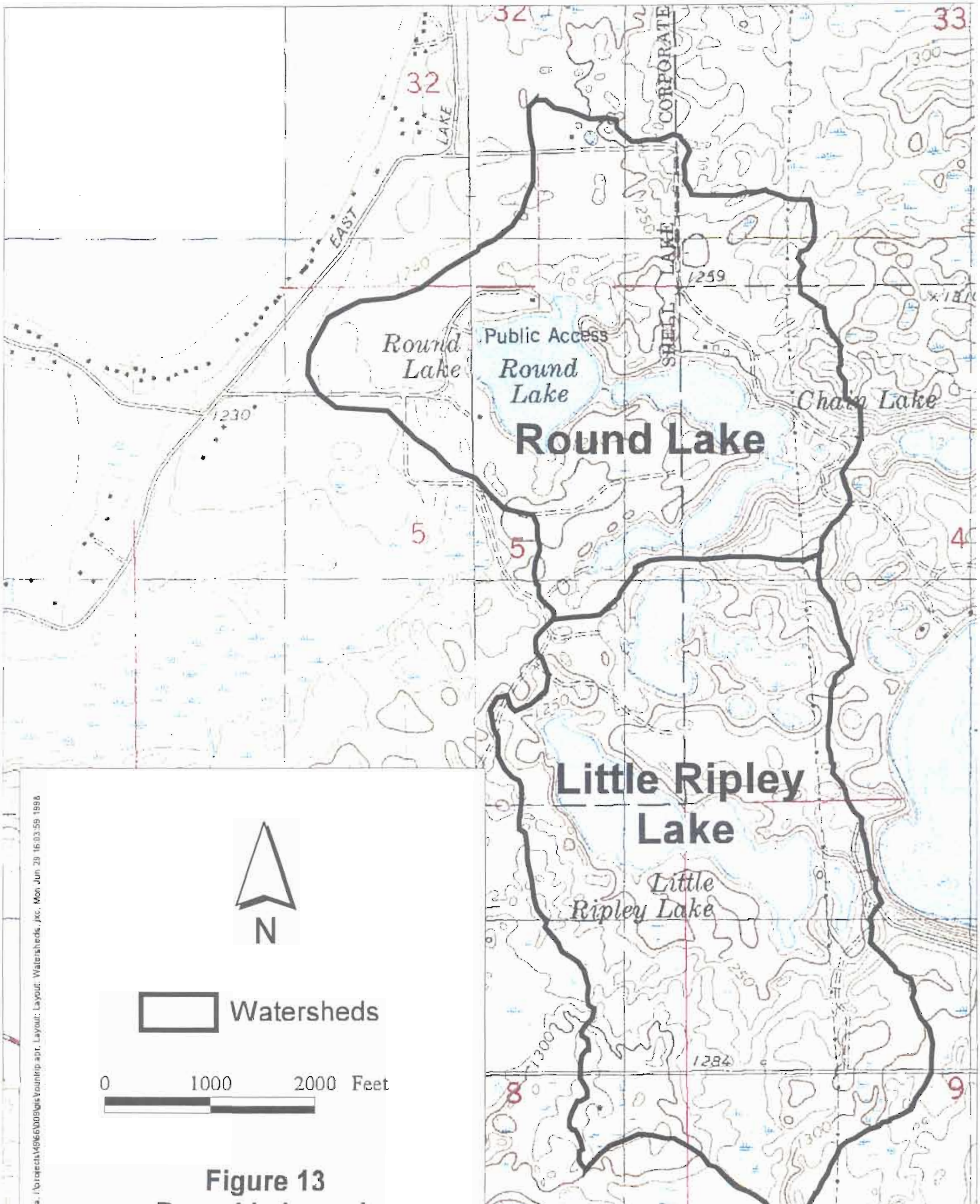

Figure 13
Round Lake and Little Ripley Lake Watersheds

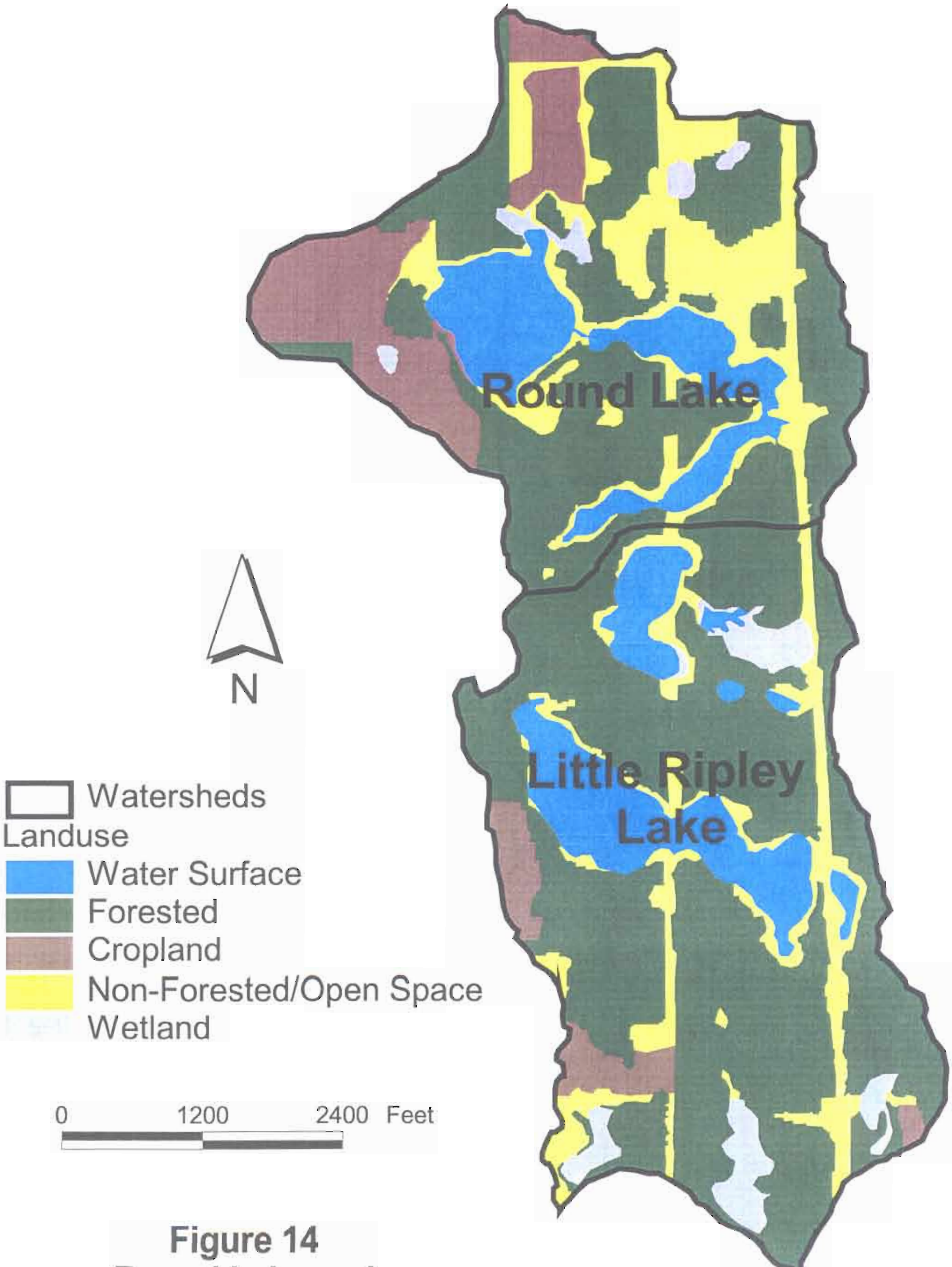

Figure 14
Round Lake and
Little Ripley Lake Landuse

5.0 Recommendations

An evaluation of 1997 Little Ripley Lake water quality data indicates the lake has eutrophic (i.e., nutrient-rich, fertile) water quality. The data indicate the lake is phosphorus-limited (i.e., the lake's water quality is determined by its phosphorus concentration). A reduction in the lake's phosphorus concentration is expected to result in an improvement in the lake's water quality and an increase in the lake's phosphorus concentration is expected to result in water quality degradation. The phosphorus concentration in the lake is a result of phosphorus added to the lake from its tributary watershed. Most of the lake's watershed is currently undeveloped and consists of forestland. Consequently, most of the lake's current phosphorus load is a natural condition, rather than the result of cultural eutrophication (i.e., caused by human activities). However, uncontrolled development of the watershed would likely result in significant degradation of the lake's water quality. Development of a management plan for Little Ripley Lake and its watershed, however, affords the opportunity to evaluate different watershed development scenarios, various management practices, and possible ordinances. Information from the evaluation can be used to determine a development plan for the watershed to protect the lake's water quality to the greatest extent possible. The following project to develop a management plan for Little Ripley Lake is recommended:

- define the annual water and phosphorus load to Little Ripley Lake from each of its subwatersheds and the aggregate total under existing watershed development conditions;
- establish a long-term water quality goal for Little Ripley Lake;
- explore various potential development scenarios and their impacts on the water quality of Little Ripley Lake;
- develop a management plan for Little Ripley Lake and its watershed which achieves its long-term water quality goal.

Evaluation of current management practices of agricultural land in the Little Ripley watershed is recommended to identify any additional opportunities for management. In particular, management practices of Highly Erodible Land (HEL) should be evaluated to determine whether further reductions in phosphorus loading to the lake are possible. It is recommended that the Shell Lake Inland Protection and Rehabilitation District work with the United States Department of Agriculture Natural Resources Conservation Service in Spooner to evaluate current and potential future agricultural management practices in the Little Ripley watershed.

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