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Leelanau County Inland Lakes Project

A Study of Development and Water Quality Within the Little Traverse and Lime Lake Watersheds

Leelanau County, Michigan

A study completed in partial fulfillment of
the requirements for the degree of
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Abstract: This project report contains the results of an in-depth study into the factors that determine or influence the quality of inland lakes. Two specific lakes; Little Traverse Lake and Lime Lake, both located in Leelanau County, Michigan, were chosen as the basis for the study. Geological, historical and climatic factors were considered in addition to human impacts. While water quality issues dominate much of the discussion, less tangible, aesthtic qualities of the lakes and human development arround the lakes and their influence on the perceived quality of the lakes were also considered. The findings of this study are intended to serve as the basis for educating lakefront property owners about the condition of their lakes and toward building a stewardship ethic for the preservation of lake quality.

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CHAPTER 1

INTRODUCTION

CHAPTER 1: INTRODUCTION

Leelanau County, Michigan is an area of unique character and interest. Seasonal and permanent homes intermingle with fruit orchards, golf and ski resorts, and a wide variety of water-based recreational activities. Important characteristics in the perceived quality of the area include its proximity to over 50 miles of Lake Michigan shoreline and numerous inland lakes. Protection of the natural ecosystems that make the region desirable to its users, while continuing or even increasing use, is of particular concern.

Lime and Little Traverse lakes are typical of the lakes in Leelanau County. Each has significant lakeside development and an active Lake Association whose members are becoming increasingly interested in what can be done to preserve the quality of its lake as use increases. Although considerable information on lakeside development and watershed protection is available, it is typically in a form that is not easily used or understood by the public. The Leelanau Conservancy, a land trust within Leelanau County, provides some assistance to the Lake Associations. Preliminary data have been collected by the Conservancy relating to water quality in these lakes. Some of these data are condensed into simplistic bulletins or flyers, which are incomplete or address only a single aspect of water quality. Because of this, available data are often ignored when developing action plans.

The issues facing residents living in the Lime and Little Traverse Lake area are common to many inland lake areas throughout the state. Rapid development around these lakes alters the natural inputs and outputs to the lake. These human impacts need not be negative or harmful to the lake ecosystem, so long as careful planning and development are considered at each step of the process. Common sources of nutrient input to the lake such as septic systems and lawn fertilizers can be prevented or corrected. Thus a need exists for a more complete and understandable source of information available to property owners in and around the lake basin.

I. Objectives

Preliminary discussions with members of the Lake Associations and the staff of the Leelanau Conservancy revealed great interest in taking appropriate actions to preserve the quality of the lakes, and a desire to make better use of the available data in a way that the average person would find understandable. These discussions led to the formulation of the following objectives:

1. Determine conditions and trends in the lakes based upon existing water quality data, and how the data collection process can be improved.

2. Make recommendations for responsible land use, development, management, and ongoing monitoring of environmental, recreational, and scenic qualities.

3. Promote a stewardship ethic through responsible use and protection of the lake and surrounding shoreline, including attention to homeowner practices, development, and improvement based on the technical data.

4. Educate individuals regarding the availability and access to community resources including the lake associations, Leelanau Conservancy, and other private and government organizations and agencies.

II. Background Information

With these objectives in mind the project team developed a framework for the subsequent research. The approach taken was to look at the lakes in terms of their natural character including a number of physical and biological factors. These included the interrelationships between geologic history, soil types, climatic conditions, vegetation types and human connectivity and interaction with the ecosystem.

Data collected by the Leelanau Conservancy for both Lime and Little Traverse Lakes were provided to the group in raw form. Many of the data sets were incomplete and un-interpreted. Additional sources of data were identified through the Michigan Department of Natural Resources (MDNR) and the Institute for Fisheries Research.

This report will address information on the watershed, the lakes, an evaluation of the lakes' current condition, suggestions relating to environmentally sensitive construction measures, septic system maintenance, landscape techniques and a discussion of concerns addressed at the Lake Association meetings and in the surveys.

Through the cooperation of residents, the Lake Association, the Leelanau Conservancy and other agencies, concerned citizens can effectively preserve and protect the lake ecosystem. Since natural environments do undergo constant change, programs of ongoing monitoring are another aspect that must be included in any such program. Recommendations about how such programs might be designed and implemented will also be included.

CHAPTER 2

THE LAKE USER SURVEY

CHAPTER 2: THE LAKE USER SURVEY

To determine which issues were of interest to local area residents, group members attended the annual meeting of each Lake Association. After a brief presentation, comments and questions about the project were solicited. Written surveys were also distributed, both to those in attendance and to all homes surrounding the lakes.

The survey instrument was designed to provide the project team with an understanding of the ways residents use and perceive their lake. It included questions regarding the types of water use and disposal (i.e. appliances, water saving devices septic system design and maintenance). Other questions attempted to determine landscaping and use of lawn fertilizers. Sections on lake uses and concerns regarding changes in the lakes. Finally the survey attempted to determine if individuals felt that the information they wanted regarding their lake was readily available to them, either through the Lake Association, or by other means.

Several problems in the survey instrument were discovered as responses were received. The use of the less specific terminology "septic system" used in some questions rather than the explicit terms "drainfield" and "holding tank" and the use of the term "buffer strip" without a specific definition is likely to decrease the validity of responses to those questions.[31] A more general problem throughout the survey instrument was improper scaling of response ranges. Overlap between numerical categories produced situations where choices were not mutually exclusive (i.e.. a septic system exactly 10 years old could be coded into either the 5-10 or 10-25 category by the respondent).[31] Thus responses to such questions must be viewed with these issues in mind.

Over half of the surveys were returned, with approximately 90% of respondents being members of their Lake Association. We must therefore assume a bias in the results due to the low response rates from residents who are not Lake Association members. Although the survey was not statistically analyzed to establish specific correlations in the responses, or to establish levels of confidence or significance of the results, answers did provide valuable insight to the project team. Issues that received high levels of response were used as a means to focus the research at topics of interest to lake area residents.

Over 85% of respondents listed additional development in the watershed as a major concern. The reasons given varied, but two issues: keyhole development, and water quality dominated. Damage to scenic quality and habitat, as well as increased boat traffic were also high on the list. (see Figures 1a and 1b)

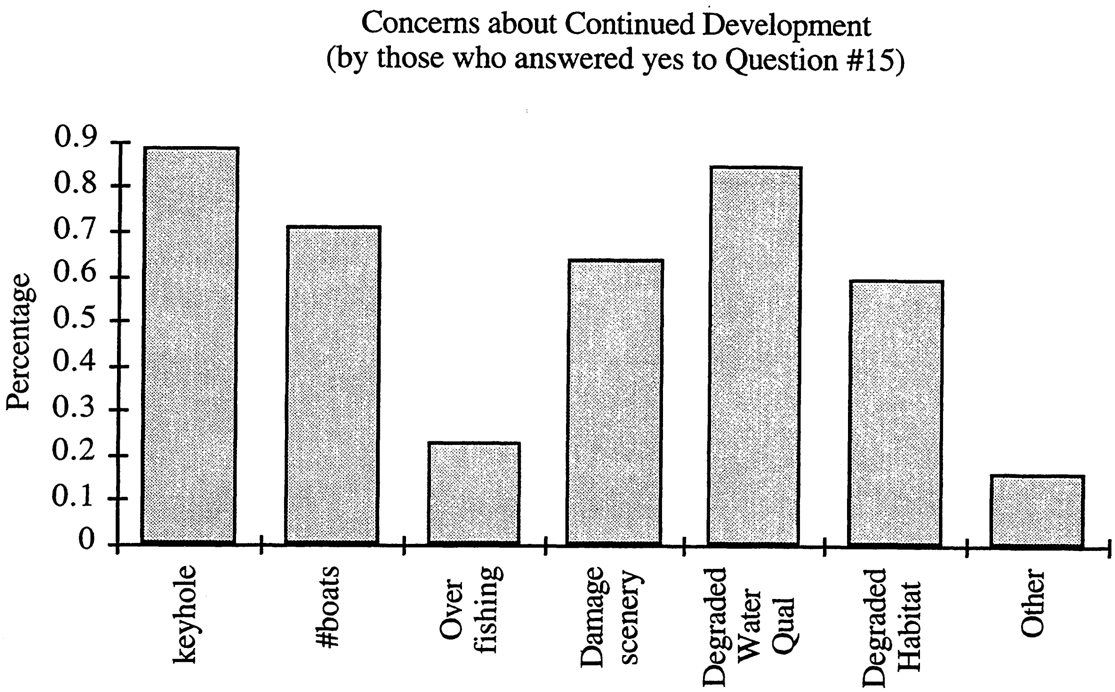


Figure 1a: Little Traverse Lake Survey question #15a

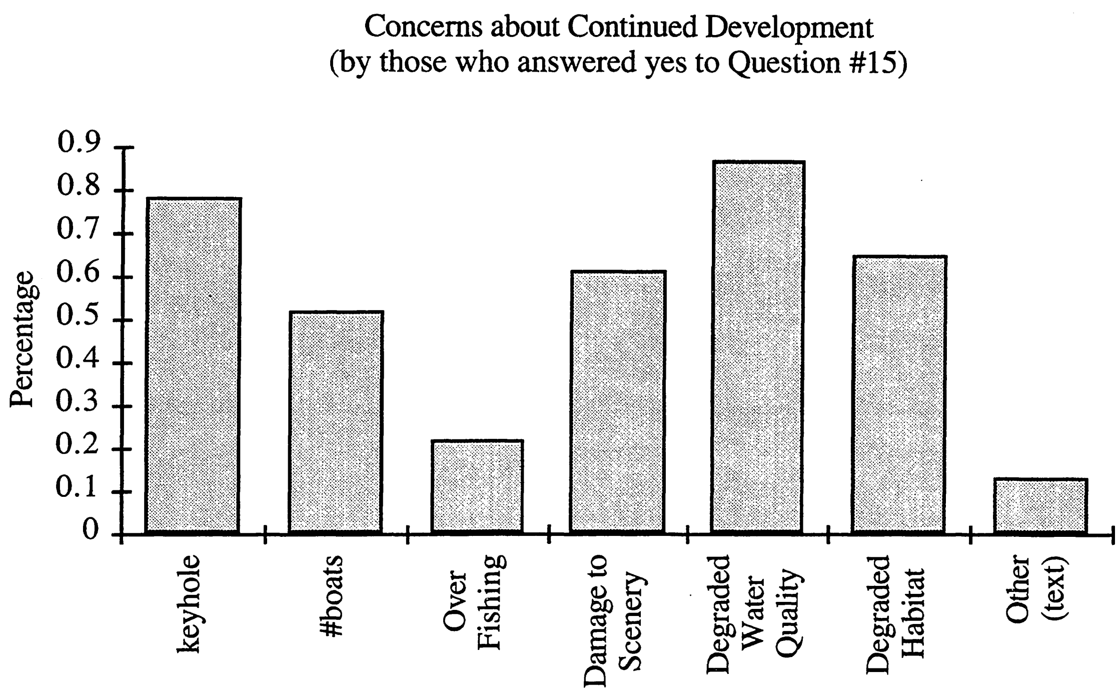


Figure 1b: Lime Lake Survey question #15a

Increases in home development in the lake area have been on the rise since the early 1950's. By the mid 1970's the number of homes had doubled on both Lime and Little Traverse

Lakes. The number doubled again by the early 1980's. Population growth is projected to continue at a similar rate into the foreseeable future.

Two-thirds of the population in the lake region is present on a seasonal basis. The majority of use occurs in the summer months of June, July and August. Many of the homes in the area are for recreational use. One can extrapolate that this high level of summer will place similarly high demands on the resources of the area. Septic system use, water for drinking and washing, and disturbance to the lake will all be at the highest levels during the summer months. The number of users on the lake in boats, fishing, water skiing and swimming can also be expected to be substantially higher during these summer months. (see Figures 2a and 2b)

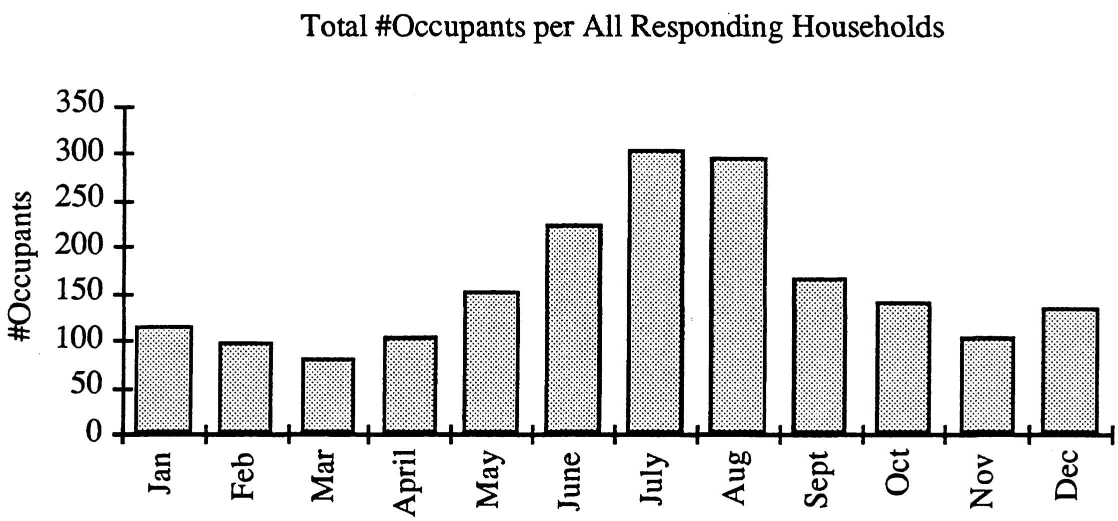


Figure 2a: Little Traverse Lake Survey question #3

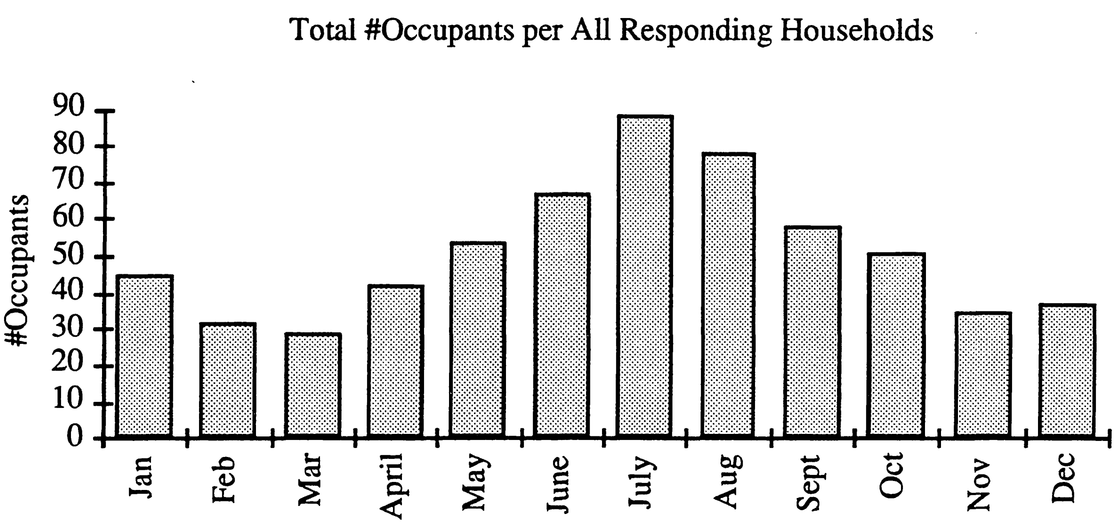


Figure 2b: Lime Lake Survey question #3

Recreational use of the lakes is also a significant reason many residents enjoy the area. Fishing and boating were top responses as well as swimming which a fair number of respondents added as a write-in response. Scenic quality was also very highly rated by respondents, being the dominant use for those respondents on Little Traverse Lake. (see Figures 3a and 3b)

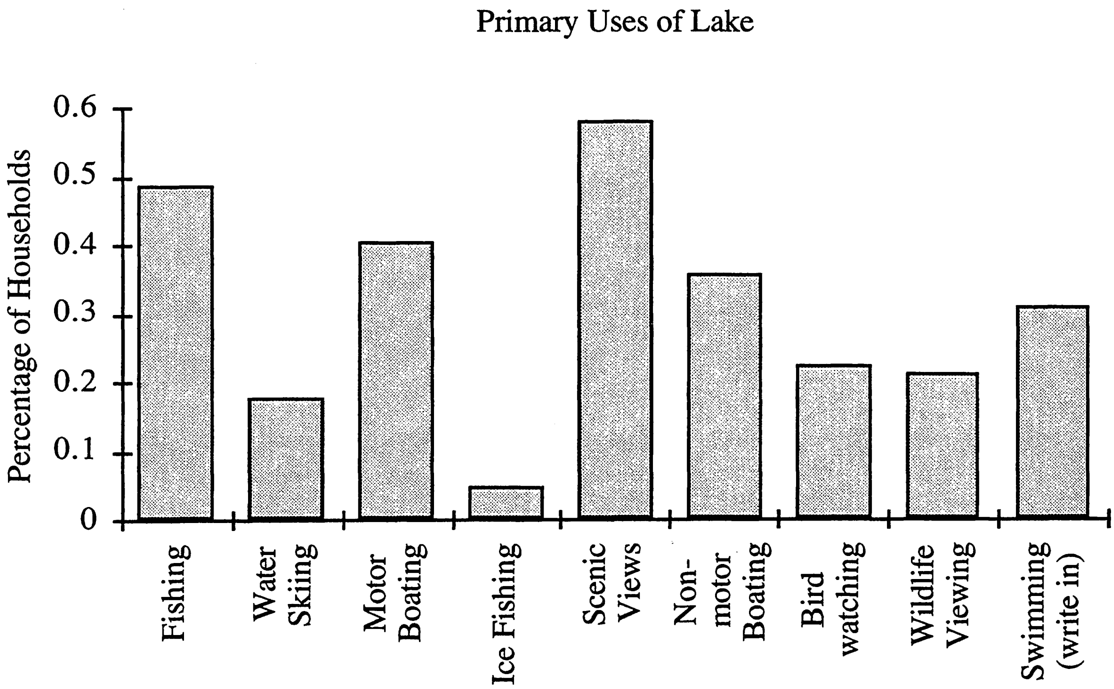


Figure 3a: Little Traverse Lake Survey question #9

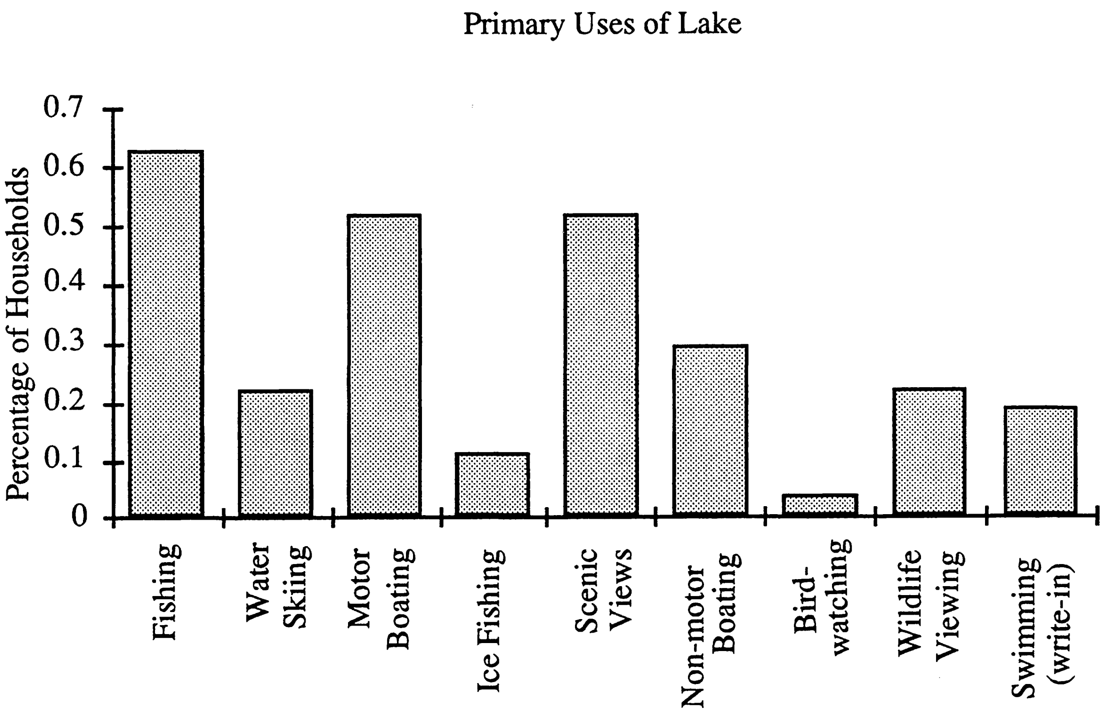


Figure 3b: Lime Lake Survey question #9

Some respondents have reported changes in the species of fish they are catching which might be one indicator of degrading water quality in these lakes. The accuracy of the species may be affected by the individual respondents ability to correctly identify and recall species taken from the lake in previous years. Since no official census of fish populations has been made by any agency these self-reported fish catches must serve as the basis for understanding potential changes in the overall species composition of each lake. The primary responses are shown in Figures 4a and 4b below.

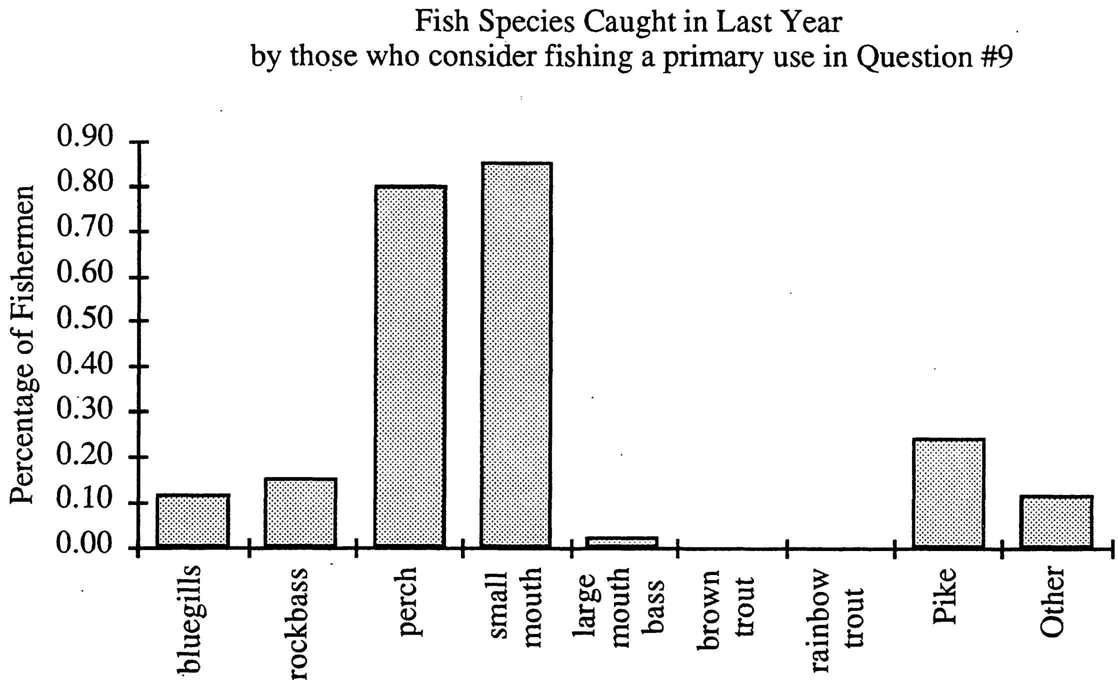


Figure 4a: Little Traverse Lake Survey question #13

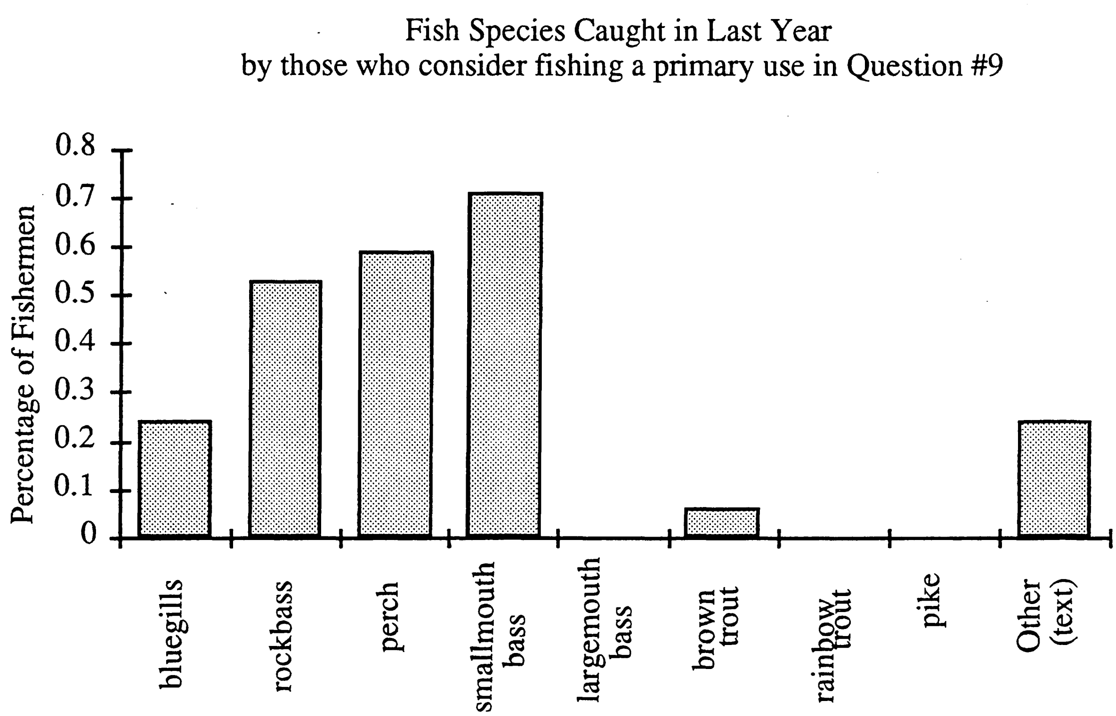


Figure 4b: Lime Lake Survey question #13

The majority of people on each lake are content with the current levels of boat traffic on their lake. There is a high level of concern that boat traffic and noise will be a problem in the previously. Keyhole development is a method by which a single lake access point is used by multiple households set away from the lakeshore, thus significantly increasing the number of users who have access to the lake.

Two sets of questions sought to determine homeowner practices related to water quality. Answers to the questions about fertilization were not sufficient to draw any generalizations about the risk of nutrient loading due to fertilizer. The questions regarding septic systems, another potential contributor to the degradation of water quality, were somewhat more useful.

Data on both the age and maintenance of systems were collected. Most of the homes in the area are using the system originally installed when their home was built. Thus the majority of systems are 10-25 years old, correlating to the high levels of development in the mid 70's and 80's. See Figures 5a and 5b.

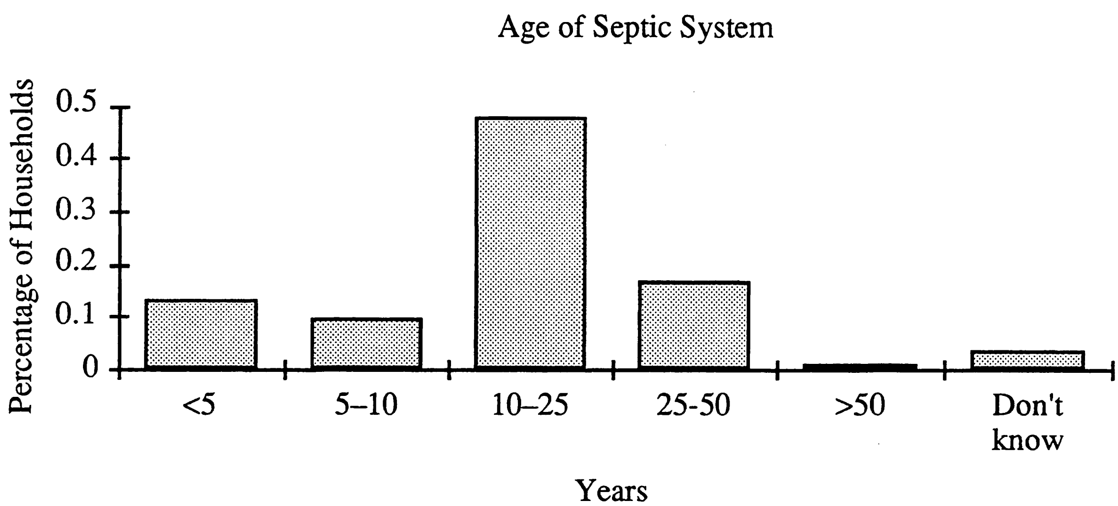


Figure 5a: Little Traverse Lake Survey question #5a

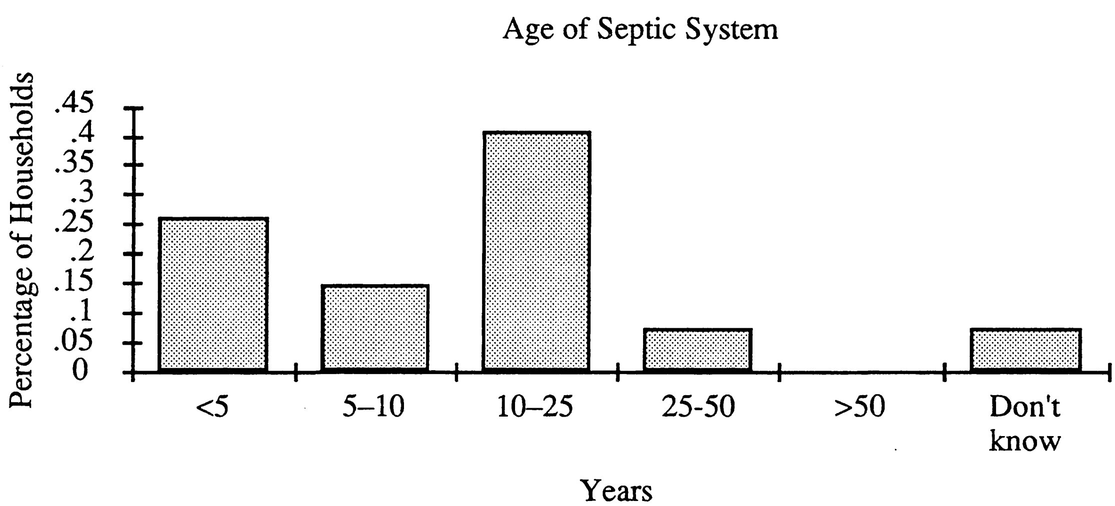


Figure 5b: Lime Lake Survey question #5a

For a septic system to be of least potential harm, current building code requires placement of the drainfield at least 100 feet from the lakeshore and wells. According to the responses received regarding placement of septic systems, a number of homes have systems that are less that 100 feet from the lakeshore. Due to the unclear wording in this question, it is unclear what respondents defined as their "septic system" when answering the question. Though many systems do meet the current building code, the risk posed by any one system is highly variable. Factors such as design and construction as well as maintenance of the system and the local soils and groundwater flow all have an effect on its function.

The issues addressed in this discussion of the survey results are discussed more fully in the following sections of this paper. Complete response data, including write-in answers and a sample copy of the survey are provided in Appendix A.

CHAPTER 3

THE LAKE AND ITS WATER QUALITY

CHAPTER 3: THE LAKE AND ITS WATER QUALITY

I. Lime and Little Traverse Lakes Watershed

Lake water quality is related to the activities within the watershed, the land area that drains rainwater and snow melt from higher elevations to a lower elevation. In one sense, Lime Lake and Little Traverse Lake each have their own watershed. In a larger context, the two lakes and the creeks that connect them are a part of a larger watershed to Lake Michigan.

A. Characteristics of the Lake Basin Affecting Water Quality

There are a number of physical characteristics of the Lime and Little Traverse Lake watershed which contribute to the natural character of the area. Most fundamental of these is the geologic history of the region. Other factors such as the size and depth of the lakes, steams and groundwater flow, climate, vegetation, and soils each have additional influences on how the water quality of these lakes is affected by any particular development project within the watershed. These characteristics are discussed in detail in the following sections.

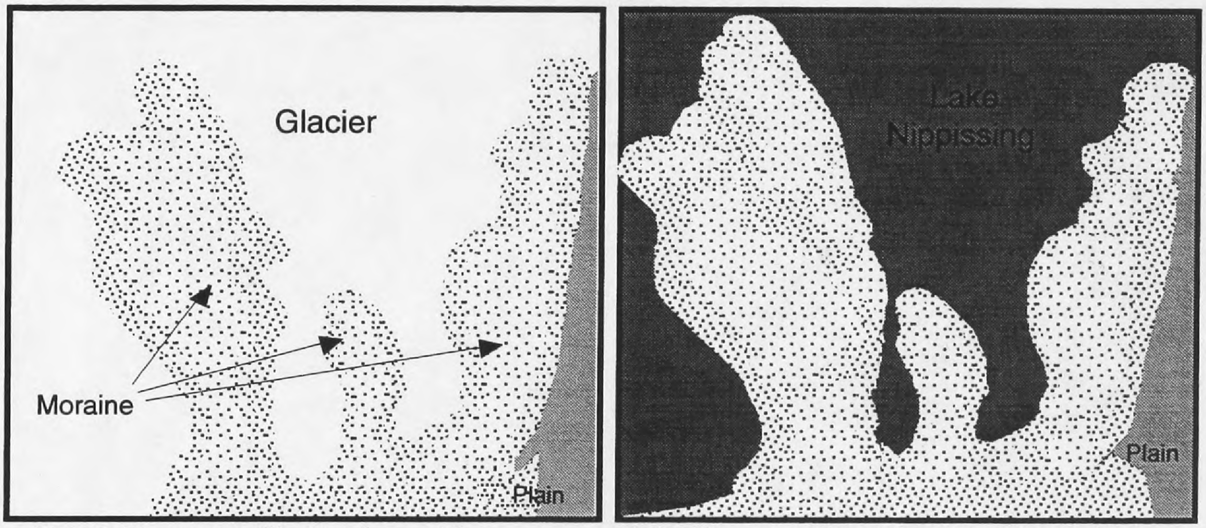
1. Geologic History and Basin Formation

Many of the processes that effect water quality in the Little Traverse and Lime Lake watersheds are governed by the underlying geology of the region. In order to understand water quality we must first understand a little about the geological processes that created and still influence the lakes.

The bedrock underlying Little Traverse and Lime Lakes is mostly shale, sandstone, dolomite and limestone. These are sedimentary rocks laid down during the Devonian period approximately 425 million years ago when the entire region was the bottom of a great inland sea. This bedrock is covered by 50 to 900 feet of glacial deposits.[36] The valley containing Lime Lake opens into Little Traverse Lake and was formed over 11,800 years ago by glacial action during the Valders Advance of the last ice age.[15] The hills on either side are a part of the Manistee Moraine and are made up of various types of rock, gravel and sand carried along by the glacier's edge, piled up and left behind when the ice receded. Because of this formation process, the hills surrounding Little Traverse and Lime Lakes contain a high proportion of sandy, loamy soil.[36]

Following the ice age, the Great Lakes basins were filled with water from ice melt. The water level rose and fell significantly several times (Figure 6). At first the receding ice opened up the rivers that drain the lakes, causing water levels to fall. Later, as the rebounding earth's crust rose with the removal of the weight of the glaciers, the drainage slowed, stopped and some rivers even reversed their direction of flow. This rebound continues today.

Approximately 4,000 years ago a single lake, Lake Nippising, occupied the basins of what today are Lake Superior, Lake Michigan and Lake Huron. It was drained both at the North by the North Bay outlet and to the South through the St. Claire region. The water level was then at 605 feet until the rebound closed off the North Bay outlet 3,500 years ago. All drainage shifted south. Water level fell slowly until approximately 3,200 years ago when the St. Claire river suddenly cut though to a layer of glacial till. The river rapidly cut a channel down to bedrock at 580 ft. which became the water level for two new lakes, Lake Michigan and Lake Huron. Lake Superior was cut off by a bedrock sill and stabilized at 605 ft.[15]

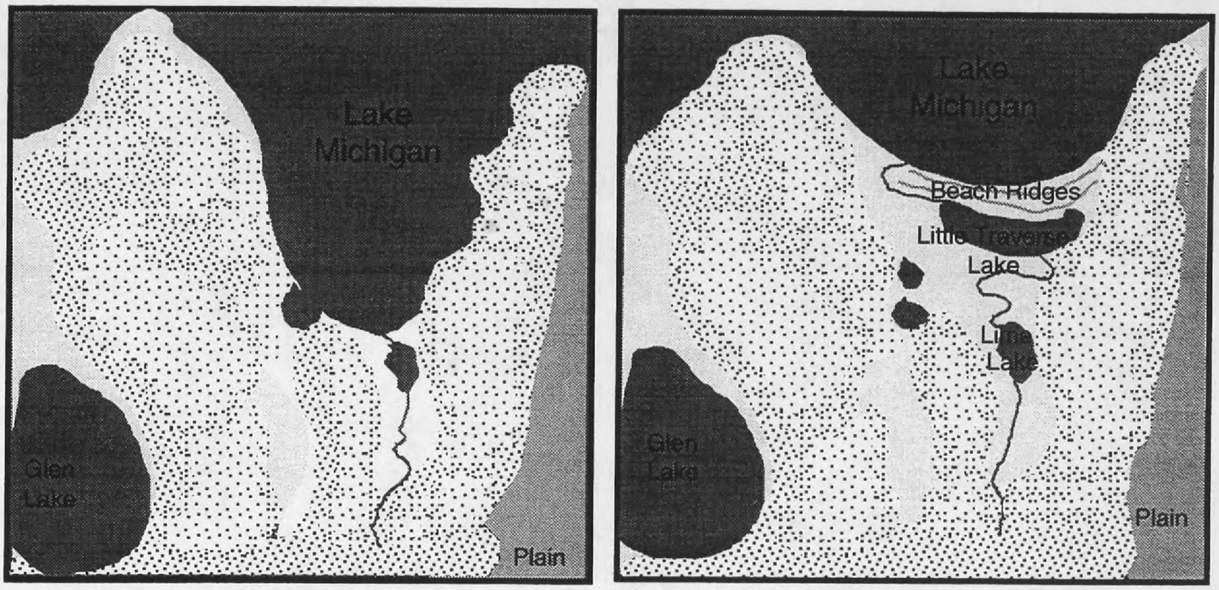


11,000 Years ago Glaciers formed the Moraines.

4000 Years ago the valleys were bays along Lake Nippissing.

Figure 6: Formation of the lakes.

Little Traverse and Lime Lakes were formed by a process called embayment (Figure 7). They once were part of a bay along the coast of Lake Nippissing. As the water levels fell with the draining of Lake Nippissing the bay gradually filled in with sand and silt deposited by outwash into the lake. Additional sand erosion from the peninsula that once extended from Pyramid Point was deposited across the bay mouth forming the shoreline of Good Harbor Bay. The stair-stepped beach ridges between Little Traverse Lake and Lake Michigan are the remains of past coastlines established during the embayment process.



3,000 years ago lakes began forming by embayment of the receding waters of Lake Michigan.

The current lakes were formed as the coastline filled in with sand washed east from pyramid point.

Figure 7: The embayment process.

The lake bottoms, especially in Lime Lake, contain a great deal of marl, composed primarily of calcium carbonate and some magnesium carbonate mixed with clay. The carbonates are essentially ground up limestone and mollusk shells scraped up from the ancient ocean floor and left behind by the glaciers.

Water levels have varied over the last few centuries as the streams draining Little Traverse and Lime lakes have occasionally been cut off, then found new channels. When water levels were low plants encroached on the shoreline. When water levels have risen the plants have been killed forming deposits of peaty sand. Peat makes up a large part of the soil in the shallows of both Lime Lake and Little Traverse Lake. The soils at the East end of Little Traverse Lake contain coarse grained sands and gravel probably washed down from Sugar Loaf Mountain.

To a large degree the suitability of the land for development and agriculture is determined by soil type. For example, soils that are too wet, too permeable or too steeply sloped are not suitable for home building. As one might expect, soils surrounding the lakes are mostly sandy. Near the lakes there are very fine-grain, silty mucks. Most of the topsoil in the region is nutrient poor and is unsuitable for grain or seed crops, but the combination of soils and climate make many areas in the region ideal for fruit orchards.[55]

2. Climate

The close proximity of Lake Michigan moderates the climate in a way that produces an optimal growing season for a variety of fruit trees (especially apples and cherries). The climate is Midwest Continental but is influenced at critical times of the year by the heat-exchange properties of Lake Michigan with somewhat cooler summers and milder winters than would be expected in other Midwest Continental areas further inland. Prevailing winds are from the west and northwest, off of Lake Michigan. The lake effect keeps temperatures cooler during early spring which delays blossoming until the danger of a late, killing frost has passed. The lake also moderates winter temperatures causing slightly milder winters than farther inland to the east.[36] Rainfall is dependable and fairly consistent throughout the growing season which aids in producing quality fruit.

Acid rain is rare in the region but does occur with a pH as low a 4.0 when winds come from the southwest. The lakes are buffered against acidification by calcium and magnesium ions in the marl bottom, whereas ground water in the surrounding hills and swamps is not.

3. Size and Depth

Little Traverse Lake is a crescent shaped lake, typical of an embayment. It is 2.1 miles long and 0.7 miles wide at its widest point, covering an area of 640 acres. It is 54 feet deep at its deepest point northwest of the center of the lake. The bottom is primarily a mixture of marls, silts and sands with marls on the south side, silts and sand on the north side, and an area of gravel bottom at the eastern end.

Lime Lake is an oval shaped morainal lake 1.6 miles long, along its north-south axis, and 0.8 miles wide, covering 670 acres. Its bottom is a mixture of marl and sand. In the northeast corner the bottom is covered with slabs and edgings from a former sawmill. The lake is 67 feet deep at its deepest point just west of the center of the lake. There is also a shallow spot near the center which some residents remember as being an island in the 1930's.

4. Lake Morphology

The morphology of a lake has a strong influence on its physical, chemical, and biological development which is a reflection on the origin of the lake as well as the events that have altered and shaped the lake since its formation during the last glacial period. A number of standard lake parameters are commonly used to describe the size and shape of a lake basin.[67]

Maximum Length (l) is the longest distance across the surface of the lake. This is the maximum length across which wind may interact with the lake without interruption by land.

Maximum Breadth (b) is the maximum distance between shores at a right angle to the line of maximum length.

Area (A) is the total surface area of the lake at mean level.

Volume (V) is the total volume of the lake basin calculated as the area of each stratum at successive depths to the point of maximum depth.

Mean Depth (z) is the volume divided by its surface area.

Turnover Time is the length of time it takes for the volume of water in the lake basin to be completely replaced by new water.

Shore Line (L) is the linear distance along the shore where the land and water intersect.

Shoreline Development (Dl) is the ratio of the shore line length (L) to the circumference of a circle of area equal to that of the lake. A lake that is very circular will have a Dl of close to one. Higher shoreline development values indicate a more dendritic lake outline which reflects the potential for greater development of littoral communities in proportion to the volume of the lake. Such lakes are likely to have increased rates of aging and filling. These parameters are given for Little Traverse and Lime Lakes in Table 1 below.

Table 1: Parameters for Little Traverse and Lime Lakes.

Parameters:	Little Traverse Lake	Lime Lake
Maximum Length (ft.)	11,088	8,448
Maximum Breadth (ft.)	3,696	4,224
Surface Area (acres)	640	670
Volume (cubic ft.)	267,000,000	521,000,000
Maximum Depth (ft.)	54	67
Mean Depth (ft.)	9.6	17.8
Turnover Time (years)	0.4	1.1
Shoreline (ft.)	27,026	22,992
Shoreline Development	1.44	1.20

5. Major Tributaries and Groundwater Contribution

The primary tributary flowing into Lime Lake is Lime Creek, originating near Maple City and entering through the swampy area at the southern end of the lake. There are several other small ground water tributaries along the West side, one just south of the public access point and one midway up the west side. There are also several springs feeding the lake in the southwestern quadrant.[14] The springs create cold spots and sometimes the up-welling water causes a noticeable disturbance at the lake surface. The lake is primarily groundwater fed (50%) from the east and west shores, which are bounded by high hills. Weed beds are thickest in the southern end, possibly due to the influx of nutrients from the ground water, springs and Lime Creek.

The primary discharge is through Shetland Creek which drains the lake from the northwest corner and then flows north and east to Little Traverse Lake. The water level in Lime Lake is maintained by a small rock dam at the entrance to Shetland Creek. In the Fall, the center rocks are removed to permit lake water level to drop, reducing ice damage to piers and sea walls during the winter. In the Spring, the rocks are replaced to raise the water level to permit people to float their boats in the shallows.

Little Traverse is primarily fed by surface water (71%). The primary tributary into Little Traverse Lake is Shetland Creek which empties into the lake at its South Eastern edge. Numerous small ground water flows enter the lake off the hills to the east and southwest with some minor groundwater flow from the south. The primary discharge is via Shalda Creek which exits the lake at the northwestern corner and flows to Lake Michigan.[14]

The streams are not the only outlets. Just as the lakes have ground water recharge they also discharge via ground water flow. A shallow unconfined aquifer of sands and some gravels extends from the surface to depths of 30 to 70 feet (Figure 8). This upper aquifer is in direct hydraulic connection with Lime Lake, Little Traverse Lake and Lake Michigan, and is recharged by precipitation within the basin.[14]

Immediately below the upper, unconfined aquifer is a silt and clay aquitard, that is present throughout the lake basin. The aquitard is composed of silts, silt and sandy clays, and pure clays. It is estimated to range from 10 to 80 feet in thickness, and provides flow separation between the upper unconfined aquifer and a lower, confined aquifer system.

Beneath the aquitard is the confined aquifer system, which probably has little or no flow interaction with Lime or Little Traverse lakes or surface water streams. A north-south cross section shows the upper surface of the lower confined aquifer rising with the land slope to the south. The recharge area for the deeper aquifer is probably the Kasson Moraine area, an elevated plateau, with thick sand and gravel deposits just south of Maple City.

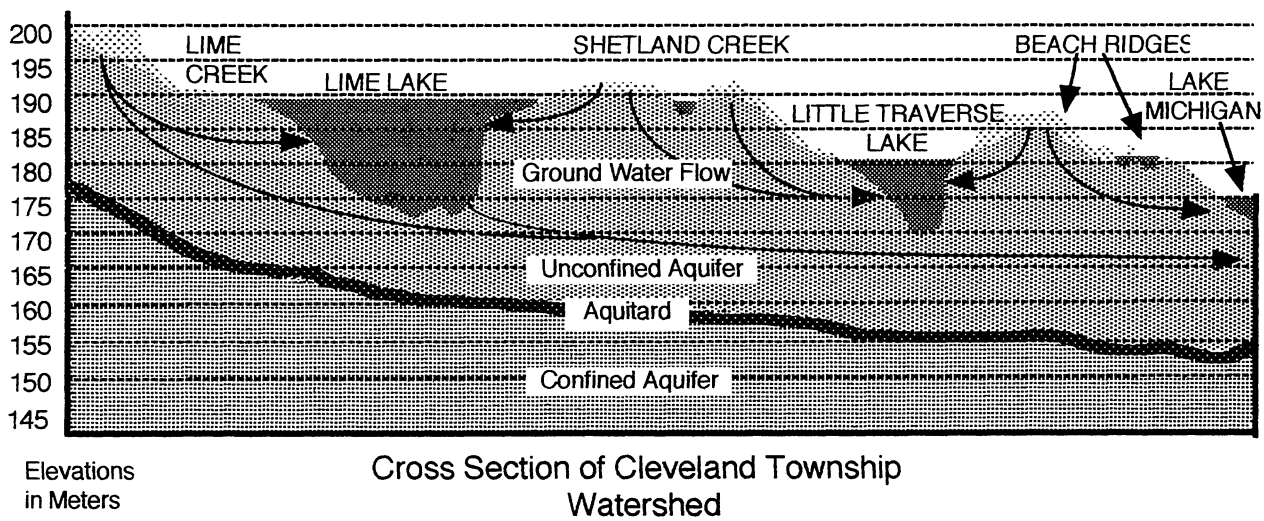


Figure 8: Cross section of the watershed.

The deeper aquifer can be excluded in determining the hydrologic budget for the watershed, as only ground water recharge and flow within the upper, unconfined aquifer is in communication with the lakes of the watershed.[14] Most residential water wells in the area draw from the lower confined aquifer. Along the north shore of Lime Lake and along portions of

Little Traverse Lake, some shallow wells only reach into the upper, unconfined aquifer and are therefore vulnerable to ground water contamination.

The hydrologic balances for the lakes were computed (by Bill Cutler of the Leelanau Conservancy, Nov. 1993) and are summarized in Table 2 below.

Table 2: Lake water balance parameters for Lime and Little Traverse Lakes.[14]

Lime Lake Water Balance	Rate of Flow	Percent of Total
Streams In:	4.9 cfs	33 %
Precipitation:	3.0 cfs	20 %
Ground Water In:	7.0 cfs	47 %
Total In:	14.9 cfs	100 %
Streams Out:	11.8 cfs	79 %
Evaporation Out:	3.0 cfs	20 %
Groundwater Out:	0.1 cfs	1 %
Total Out:	14.9 cfs	100 %
Little Traverse Lake Water Balance	Rate of Flow	Percent of Total
Streams In:	15.3 cfs	71 %
Precipitation:	2.8 cfs	13 %
Ground Water In:	3.4 cfs	16 %
Total In:	21.5 cfs	100 %
Streams Out:	18.4 cfs	86 %
Evaporation Out:	2.8 cfs	13 %
Groundwater Out:	0.3 cfs	1 %
Total Out:	21.5 cfs	100 %

Note that Lime Lake is predominantly fed by ground water. Little Traverse Lake receives most of its water by surface water recharge. Note also Little Traverse Lake's higher total flow. The nominal turnover for the lakes is the time required to completely change the water in the lake. It is computed as the total volume divided by the total flow thus:

Lime Lake = 521,000,000 cu Ft ÷ 14.9cfs = 3.5 x10 7 sec = 1.1 years

Little Traverse Lake = 267,000,000 cu Ft. ÷ 21.5 = 1.24 x 107sec = 0.4 years

The average water level in Lime Lake is 617 ft. (188 m), 23 ft. higher than Little Traverse Lake. The mean water level for Little Traverse lake is 594 ft. (181m), 14 feet higher than the mean water level of Lake Michigan.[36] The water levels in Lake Michigan have varied by as much 5.25 ft. during the last 30 years. During periods of high sustained westerly winds the water levels along the shore of Good Harbor Bay can rise by as much as four feet.[36] Whenever the water level in Lake Michigan rises it raises the water table in the immediate vicinity of the shoreline. Water will continue to flow, but not with the same velocity.

B. The Watershed

The watershed, as it exists for Lime and Little Traverse Lakes, is fairly extensive. Neither lake has a truly independent watershed, but rather, the lakes are interconnected. Most apparent is the connection between the lakes via Shetland Creek. Due to the nature of the soils both surrounding the lakes and in the watershed as a whole, there is also extensive groundwater movement throughout. These soils also influence the way in which home development or other land uses can be accomplished around the lakes, while still maintaining water quality.

1. Geography

The combined Lime and Little Traverse Lake watersheds include most of Cleveland Township. The immediate watershed of Little Traverse Lake includes nearly 2,400 acres. In addition, water from Lime Lake comes from a watershed which drains an additional 8,040 acres and extends as far South as Bright Lake. Through sandy soils, groundwater may travel as much as 15 meters per day.[15]

2. Soils

The soil is where geology, biology and climate meet. Geology provides the raw materials and topography. Biological organisms and climate work together to form the soil. The effect of weather breaks down the materials mechanically and may move them from place to place or mix them together. Climate also determines to some extent the biological activity in the soil and plants which make use of the soil minerals and cycle organic materials into the soil.[55]

The characteristics of a soil in any particular location are directly related to a number of factors known as soil-forming processes (Figure 9). These are: the physical and mineralogical composition of the parent material; the climate during soil formation; the plant and animal life on and in the soil; the relief, or topography; and the length of time over which these soil-forming processes have taken place.

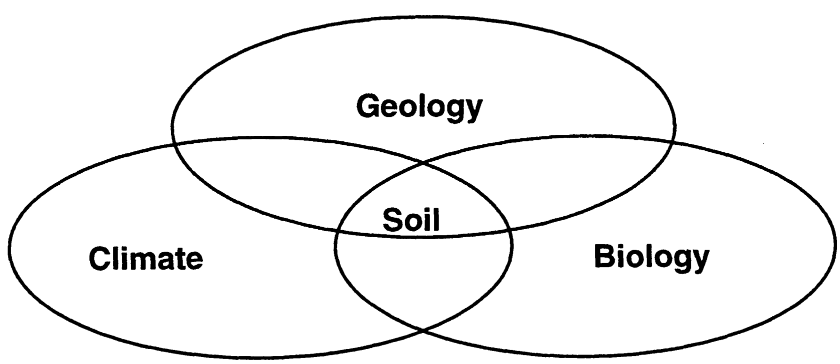


Figure 9: Components of soil-forming process.

Climate, plants and animals are active factors in soil formation. These act upon the parent material and slowly begin to change it into a soil with genetically related layers called horizons. Physical factors, such as relief, have an influence on the local micro-climate and the plants and animals that may live there. Parent material, the mineral component from which the soil forms, also influences the type of soils which develop from them.

a. Soil Forming Factors

Parent material is the unconsolidated mass from which the soil forms. In Leelanau County the parent material was largely deposited by the last glaciers present in the area. It was left in the forms of glacial till, outwash deposits, lacustrine deposits and organic material. These terms are defined as follows:[55]

Glacial till is material laid down by glaciers directly with a minimum of water action, thus the material is unsorted and contains materials of all sizes. There are likely to be rocks or pebbles with sharp corners indicating a lack of wear by flowing water.

Outwash materials are materials deposited by water which ran off the glacier as it melted. The particles are of various sizes based on the speed of the water that carried them, larger particles fell out first and smaller ones were carried further downstream. This results is deposits that consist of particles of similar size such as gravel, sand or sandy loam.

Lacustrine deposits are materials that settle out in still water such as lakes or melt pools. Typically only the smaller particles of sand, silt and clay have made it far enough downstream to reach these pools of still water and these deposits are typically made up of these finer materials.

Organic material is formed by the accumulation of organic materials which have collected in depressions and small lakes. Over time, these areas fill with dead and decomposing organic matter which may muck, mucky peat, or peat.

Plants and animals act on the soil forming process by contributing organic matter and nitrogen to the soil, both when leaves and branches fall and when they die. Roots create openings and channels which allow water and air to penetrate into the soil material, and add organic matter as they die. Bacteria in the soil help to break down these materials making them available to growing plants.

Climate determines what plant and animal life will be present as well as the availability of water which has a part in the weathering, or breaking down, of soil materials and the movement of them by water or wind. In combination with the dissolving properties of water, temperature also has an influence on the rates at which chemical reactions occur in the soil. The proximity of the Great Lakes may have influenced the particular temperatures and climate in which these soils formed.

Relief has a number of effects on the soils of Leelanau County through its influence on the runoff and drainage patterns of the region. These variations in relief provide the well drained soils of the ridges and uplands while also influencing the poor drainage and cool areas of the low depressions. The quality of drainage also influences the amount of air that is able to enter the soils as well as soil color. Well aerated soils oxidize and are therefore brightly colored by the iron and aluminum content. Poorly aerated soils tend to be dull gray in color.

Time, of course, is the integrating factor. Formation of the distinct horizons in the soil occurs over long periods as the other factors have a chance to operate. As leeching occurs, materials near the surface are carried deeper into the soil facilitating the formation of the horizons. The silicate clay materials and calcium carbonate will be carried down into the deeper soil and iron begins to oxidize. Iron may be reduced and translocated downward over time in a process called gleying in poorly drained soils.

b. Land Use and Soil Type

The soils present on a particular site have a direct influence on the type of development it will support. When considering sites for the building of roads, homes, sewage disposal systems or any other artificial structure there are a number of soil properties that need to be considered in determining the suitability of the site. Some of the most important characteristics are the shear strength, plasticity, compaction characteristics, shrink-swell characteristics, water capacity, pH, permeability and drainage. Topography, depth to the water table and depth to bedrock are also important.[55]

Shear strength is a measure of the cohesiveness of the soil. It, along with plasticity, compaction characteristics and shrink-swell characteristics are key factors in determining the weight bearing capacity of the soil and its ability to support roads or building foundations.

Plasticity is the tendency of a soil to deform under pressure. Poorly graded soils, those with relatively uniform grain size, tend to have high plasticity,

Compaction and shrink-swell characteristics are also important. Well graded soils, those with a wide range of grain sizes tend to compact well and actually become more stable when compressed. Compaction of soil at construction sites and built-up areas increases runoff from two to ten times the runoff in a natural site with the same soil type. The result is flooding and sediment deposition in the lower lying areas. A number of preventative measures may be taken to reduce this type of erosion. Soils containing significant amounts of certain types of clay may shrink or swell in response to changes in moisture content. Excessive shrinkage and swelling can be destructive of roads and building foundations.

Soil water capacity is the ability of the soil to hold some water of use by plants. The value is calculated as the difference between field capacity, the maximum amount of water the soil can hold, and the permanent wilting point, the dryness at which plants wilt beyond recovery. The available water is influenced by the soil texture and organic matter content. Additional concerns in developed areas involve the landscaping of home sites. Soils with deep rooting zones, good organic and nutrient content, and loamy texture are preferable for plant growth.

However, when the soils around a home are not ideal, it is important to know the type of soils present so that appropriate plants can be selected.

Soil pH is a measure of the acidity of the soil and is another major determinant of the types of plants that will grow on a site.

Soil permeability is a measure of the rate of water movement downward through the undisturbed soil. The speed at which water moves is determined mainly by the texture, structure, and consistency of the soils and is expressed in inches per hour. It is a key factor in determining site suitability for septic systems. The soil must be permeable enough to permit waste water to percolate through the drain field but slowly enough for microbes in the soil to have time to break down the waste materials before the wastes reach ground water.

Soil drainage permits the movement of water through a site. It is a result of the combined effects of soil permeability and topography. Drainage and water movement in the soil are important in understanding development potential of an area, including limitations for septic tank systems and filter fields. Residential development on wet or poorly-drained soils, such as those of the Roscommon series, can lead to problems such as wet basements unless some artificial drainage system accompanies the construction.

Depth to the seasonal high water table is the shallowest depth to which the water table rises in winter or early spring.

Depth to bedrock is not a key concern in Leelanau county because the bedrock is very deep.

c. Soil Classifications

Several classification schemes are used in describing soils. Each is geared towards different users. For example the United States Department of Agriculture system is used by agricultural scientists, the American Association of State Highway Officials [AASHO] system by highway engineers, and the Unified soil classification system is preferred by some engineers. Important characteristics for engineering uses are discussed briefly in the following section.[55]

Soils occur in natural layers called horizons. The sequence and character of these horizons from the surface down to the parent material is used as a means to classify soils. Soils that have profiles that are almost alike are grouped into the same series. Though soils in a series can differ in texture and slope of the surface layer, the arrangement of the underlying horizons is similar. Depths to each major soil horizon are indicated in a typical profile. If a minor horizon with significant properties is also present, it will be included in the soil description as well. Depths are varied in different locations within a soil type and are understood to be representative rather than precise values. The organic soils in the county are classified based on the first 42 inches from the surface.[55]

d. Soil associations in the watershed

The watershed soil map shown in Figure 10 shows the four general soil associations in Leelanau County. These associations represent portions of the landscape that have distinctive patterns of soils, normally consisting of one or more major soils (for which the association is named) and at least one minor soil. The soil associations give a good generalization of which tracts of land are suitable for a particular use, woodland, wildlife area or in planning projects such as recreational facilities or community developments. Specific placement of buildings, roads or crop types should be based on more specific soil maps than the one below (Figure 10).

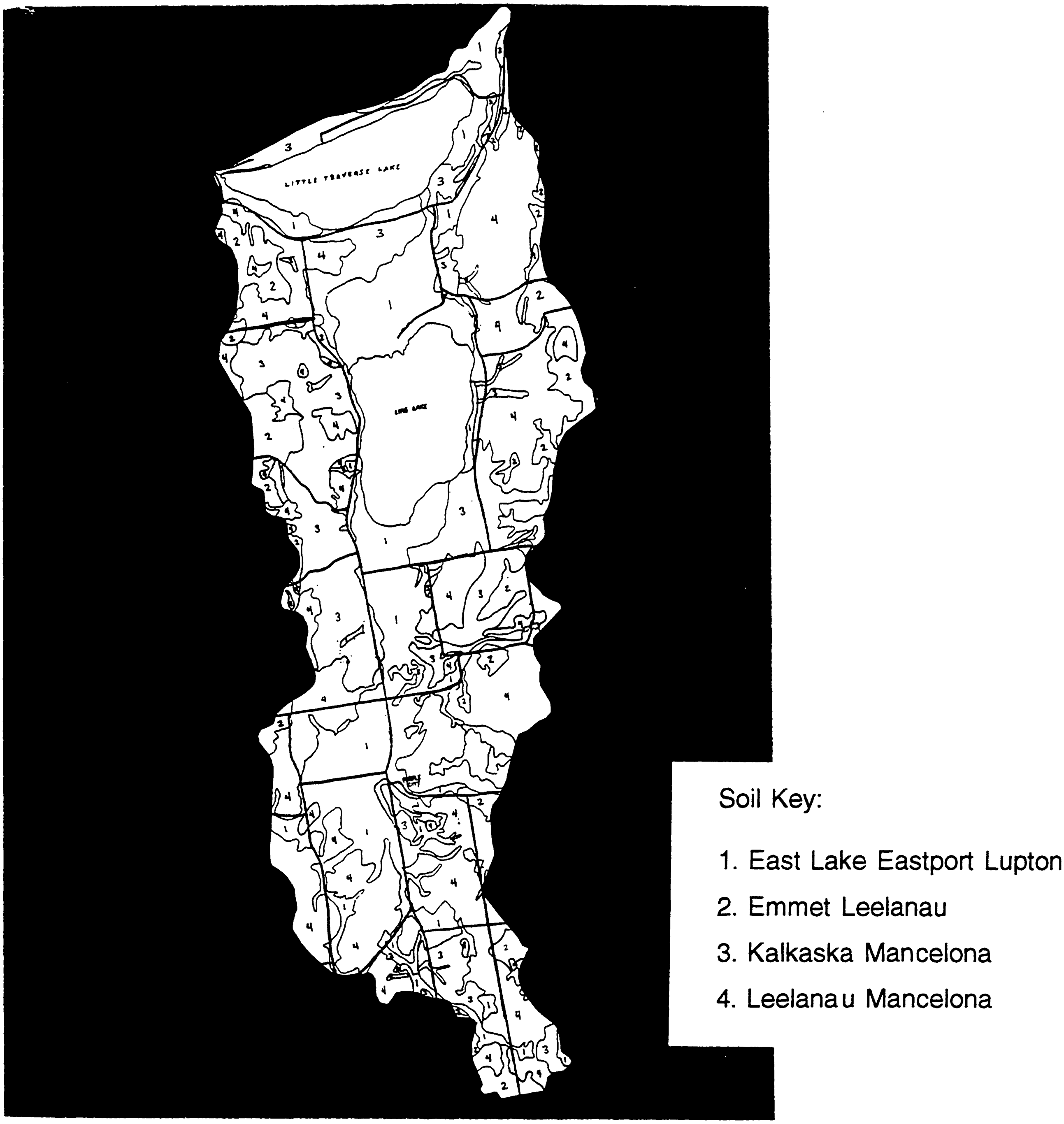


Figure 10: Soil associations in the watershed.

i. East Lake-Eastport-Lupton association

These are well drained and moderately well drained, nearly level to gently sloping, sandy soils, and very poorly drained, nearly level, mucky soils; on lake terraces and beach ridges. Approximately 45 percent of this association is East Lake soils, 10 percent is Eastport soils and 10 percent is Lupton soils with the remainder being minor soil types.

East Lake soils are nearly level to gently sloped and moderately drained to well-drained, occurring on beach ridges. The surface layer is very dark grayish-brown loamy sand about eight inches thick. At depths of about 26 inches there is a calcareous sand and gravel.

Eastport soils are level to nearly level and well drained, occupying lake terraces. The surface layer is about eight inches thick with black sand over grayish-brown sand. Subsoils are dark brown followed by dark yellowish-brown.

Lupton soils are low lying, level soils. They are primarily organic and poorly drained. The surface layer is typically a black granular muck about 14 inches thick, above a more massive black muck followed by a dark reddish brown layer at about 30 inches.

Major uses of these soils include orchards, pastures, and woodlands. Terraces adjacent to lakes are commonly used for residential building sites. Orchards are well suited to favorable sites on the well drained soils of this association, however, fertility is low in all these soils and available water capacity is low in the well drained soils. Maintaining fertility and erosion control are primary management concerns.[55]

ii. Emmet-Leelanau association

These are well-drained level to very steep, loamy and sandy soils on moraines and till plains. Approximately 35 percent of the association is Emmet soils and 25 percent is Leelanau with the remainder being minor soil types.

The Emmet is a grayish-brown sandy loam followed by a three part subsoil. Leelanau soils are well-drained and dark grayish-brown sandy loam at the surface. The subsoil is in three parts of varied color below which lies a pale brown calcareous sandy loam.

The soils of this association are not as fertile as those in the Emmet-Omena, but cherries, apples, peaches and plums are well suited to favorable sites on these soils. Other crops do moderately well. Management concerns include erosion control and maintaining fertility.[55]

iii. Kalkaska-Mancelona association

This well drained association lies on nearly level to strongly sloped terrain on outwash plains. The surface layer of the Kalkaska soils is gray sand about 7 inches thick. A three layer sand subsoil lies below. The soils are sandy and similar in character though the Mancelona is made up of loamy sands rather than sand alone as with the Kalkaska.

Native woodlands are still common on most of the sites in this association due to its poor characteristics for agricultural use. Fertility and water content are low and blowing of the soil can be a problem in managing these soils.[55]

iv. Leelanau-Mancelona association

These soils are well drained strongly to very steeply sloped, sandy and located on moraines. This is one of the more hilly associations in the county with complex slopes ranging from strongly sloped to very steep.

Leelanau soils have a dark brown or grayish brown sand layer on top. There is a three part subsoil, two layers of loamy sand followed by sandy loam. A brown calcareous sandy loam lies below the subsoil.

These soils are severely limited in their usefulness for crops or orchards due to the steep slope and low fertility. Water holding capacity is also quite low. Runoff from these areas can create problems in the more level areas lying below. If runoff is carefully controlled, some sites in this association are acceptable pasture.[55]

e. Planning Considerations

By examining soil maps, engineers can make preliminary determinations about site suitability for development and for what type of development. In most cases, additional studies at the exact site of a project within a larger soil association or soil type are critical.

Since the soils in the county are not all suitable for every possible use, planners must consider which sites can best withstand development, not only for structures, but also the streets and utilities that must lead to those areas. Some sites are better reserved for other uses such as agriculture, pasture or forest land.

Foundations are most stable when built on soils that have low shrink-swell potentials such as the Emmet, Leelanau and Mancelona series soils. A high organic component causes instability, as in the Lupton series. Other low lying soils also tend to have severe limitations for building due to their propensity to flooding.

High water tables, even if only seasonal, can prevent a septic system from functioning properly. Conversely if soils are too permeable, such as the sandy soils of the Eastport and

Kalkaska series, septic system effluent may get into groundwater without having time to properly filter.

Furthermore, erosion is a common problem of soils on steep slopes with soils in groups such as the Emmet series. Erosion is of particular concern in conjunction with construction.

Three generalized ratings of soil limitations are commonly applied to any given use. *Slight* limitation means that the soil is fairly free of limiting factors or these factors are easily overcome. *Moderate* refers to soils in which limitations need to be recognized but can still be overcome with careful design and management practices. *Severe* refers to soils that have significant limitations making its use questionable.[55] Table 3 details suitability for various uses.

Table 3: Developmental suitability of the four primary soil associations.[55]

Soil Types within the Watershed

Soil Associations	Suitability for Roads& Streets	Suitability for Home Foundations	Suitability for Septic Systems
1 **East Lake-Eastport Lupton**	Moderately well to well drained Fair to good stability Some possible cuts/fills needed	Moderately well to well drained Fair to good shear strength Slight compressibility Rapid permeability	Moderate: rapid permeability possible contamination of ground water Severe on slopes >18%
2 **Emmet-Leelanau**	Moderately to well drained Fair stability Moderate frost action	Moderately well to well drained Fair shear strength Slight compressibility Moderate to rapid permeability	Slight: moderate permeability. Moderate: on slopes 12-18% Severe on slopes >18%
3 **Kalkaska-Mancelona**	Moderately well drained Poor stability High water table (possible flooding)	Moderately well to well drained Good shear strength Very slight to slight compressibility Very rapid to rapid permeability	Moderate to severe: possible ground water contamination especially on poorly drained sites
4 **Leelanau-Mancelona**	Moderately to well drained Fair stability Moderate frost action Some possible cuts/fills needed	Moderately well to well drained Fair to good shear strength Slight compressibility Rapid permeability	Slight: possible ground water contamination\ on flat land. Moderate: on slopes 12-18% Severe on slopes >18%

f. Soil Management

There are several basic principles of soil management that are important in maintaining or improving soil quality. Necessary components include an adequate supply of plant nutrients and organic matter, a good root zone, and a proper balance of air and water in the soil pores. Some soils in the watershed are poorly drained and require artificial drainage systems to remove excess water to improve the air-water ratio in the soil. It is often difficult to locate suitable outlets for such drainage systems. Good soil structure, including an adequate organic component, is beneficial to proper soil drainage. Those areas that are low lying and poorly drained are also subject to shorter growing seasons due to frosts in late spring and early fall. On sandy sites, common to the county, it is often necessary to improve the organic matter content, soil tilth, and nutrient content while also preventing erosion of the topsoil.[55]

All soils in the watershed are suitable for forestry uses although not all soils are suitable for all species. Some areas are more appropriate to coniferous species and others are better suited to hardwoods. Of course, these soil differences are important in choosing the species to use in landscaping.[55]

g. Public Health Concerns

There are obvious concerns related to the locating of certain types of systems including septic systems and individual wells. Similarly, there are public sites such as sanitary land fills or sewage lagoons. The locations of these types of systems and land uses is critical and the soils, topography, and drainage must be taken into account to prevent contamination of water supplies. Sandy soils in the Deer Park and East Lake series, for example, are very permeable and may allow pollution to migrate through the soil.[55]

h. Recreational Uses

High impact recreational use of soils that are poorly drained such as the Lupton or Houghton series is not practical. High traffic uses such as campsites, picnic areas or playgrounds will not hold up well unless built on very stable and resilient soil types. Fair to good soils for these high traffic uses include level sites of sandy or loamy material such as the well-drained Emmet, Leelanau, and Mancelona soil series. Sloped areas are limited for some uses but may be suited to paths and trails. These soils dry out quickly following rain and are therefore firm enough to withstand foot and even vehicular traffic.[55]

C. Human Use and Impacts

1. Early Settlement

Archaeological evidence exists to indicate that the Leelanau area was inhabited by Native Americans as long as 3,000 years ago. Pottery and other remains of a fishing station near Glen Arbor have been dated at between 200 - 600 AD.[66]

The first European explorers arrived in the area in 1624. The earliest economic activity centered on the fur trade. Beaver, fisher, marten, otter and muskrat were heavily trapped. Beaver pelts were the most prized and were the defacto currency in the region well into the 19th century. The fur trade peaked around 1830 with the animal populations nearly depleted. Small farms and lumber slowly replaced trapping as the main commercial activities.[70] The sandy soils proved unsuitable for most crops. By the early 1800's lumber became the dominant industry.[22]

The early settlement of Leelanau County by Europeans was initially located along the shores of Lake Michigan and timber was extracted for use as fuel on passing steamships. By the mid 1800's a substantial number of farmers had settled in the county.[70] Two of the earliest settlements in the immediate vicinity of Little Traverse and Lime Lakes were the towns of North Unity (est. 1855) and Good Harbor, (est. 1863). North Unity was largely destroyed by a fire in 1856. The only remaining structure is the Lutheran Church near the corner of M-22 and Townline Road. Good Harbor included a pier, a lumber mill and a grist mill.[66]

Several lumber mills were also built and some amount of timber was extracted from the county through the later part of the century. Several mills were constructed including a grist mill on Shetland Creek between Lime and Little Traverse Lakes by H.D. Pheatt. No village in the county gained any significant commercial importance. By the late 1800's the county was recognized as being unique in its resources of climate, soil and scenery and a promising fruit growing region.[70]

2. Deforestation and the End of the Logging Era

Lumbering declined near the end of the century as the forests were depleted by years of over-harvesting. By 1906 Good Harbor was a Ghost Town. The area was turned over to light farming and small orchards. In winter the local population cut ice from the lakes for shipment south to fill ice boxes. The small ice industry continued into the late forties but died out with the advent of household refrigerators.

Following the logging era some areas returned to more natural woodlot conditions. These woodlands are valuable resources in their own right. They reduce storm run-off and soil erosion, and lend substantially to the rural, scenic character of the region. and provide wildlife habitat.[36] Woodlands cover approximately 927 acres of Cleveland township. Common species found in the woods are: maple, beech, elm, and aspen, with some black cherry, ash, basswood, birch hemlock, white and red pine intermixed. The dune soils and sandy lake plains are covered mostly with jack pine, white pine, red pine, soft maple, aspen and juniper. The swampy lowlands contain white cedar, balsam fir, black spruce with elm and soft maple intermixed.[36]

3. Agriculture

One small farm is still operating at the east end of Little Traverse Lake and another along route 667 between Little Traverse and Lime Lakes.

Agricultural chemicals used in the area include pesticides, fungicides and miticides. The actual spraying of the chemicals does not pose a significant threat to ground water because they are foliar applied. These chemicals are generally considered to present a small risk potential for leaching but a high risk for runoff. Most of the chemicals carry warning label statements warning of toxicity to fish and aquatic invertebrates.[36] It is highly likely that some of these chemicals will be found in the lakes or groundwater.

4. Recreational, Commercial and Industrial Development

The residential, commercial and industrial development that occurred were concentrated in several villages along the Great Lakes shores. The remaining portions of the county remained in scattered forests, wetlands and agriculture. This history, especially the lack of any large-scale industrial development, has allowed the county to look towards smaller-scale tourist services, seasonal and residential homes and recreational uses such as golf, skiing, and water sports.

Home building impacts the environment in a number of ways. Initial construction involves clearing land of vegetation for access roads and the actual lots. This activity leaves the highly erodable soils very vulnerable. Even after construction is completed, roads remain as pathways for accelerated water runoff and soil erosion. A recent trend is toward ridge line development with homes built atop what were wooded ridges. Trees are cleared to afford the homeowners a nice view of the area but in the process the aesthetic appearance of the ridge itself is reduced and runoff is increased.

Little Traverse Lake is surrounded on most of its perimeter by small cottages on wooded lots. Along its Southern edge there are some rather narrow lots where route 22 comes very close to the lake. The Sugar Loaf Mountain ski slopes and golf course are within the watershed at the southeastern side.

Planting lawns and application of lawn-care chemicals can have a significant effect on water quality. Using too high a concentration close to the water's edge virtually ensures that these chemicals will find their way into the lakes. Home washing machines and dishwashers may also be a source of phosphates in ground water unless low phosphate detergents are used. Many lawn fertilizers are also high in phosphates which is a primary nutrient for algae growth. Some seasonal homeowners pour automobile antifreeze into their drains in order to prevent the traps from freezing while the house is vacant during the winter. While small amount of toxic ethylene glycol used may not pose much of a threat to the lake, it is still preferable to use a non-toxic antifreeze containing propylene glycol instead.[36]

II. LAKEWATER QUALITY

There is no definition of water quality which will satisfy everyone. Each user of a lake will have her/his own perception of how the water should be according to their intended use. The Environmental Protection Agency EPA sets minimum standards for the quality of drinking water in this country. This may be of some importance since the lake is feeding some of the wells in the unconfined aquifer. Most swimmers like crystal clear water, a sandy bottom substrate, and no weeds. The Michigan Department of Natural Resources (MDNR) sets minimum standards for recreational activities, which will be discussed later on. Most motor-boat owners prefer lakes without an abundance of weeds which could get caught in propellers. Some canoeists and bird-watchers may prefer to have an abundance of emergent vegetation and overhanging terrestrial plants to provide habitat for wildlife. A fisherman also has certain perceived notions of water quality depending on the types of fish he/she is trying to catch. Fishermen seeking cold-water fish species such as trout would require that the lake be very clear, relatively deep, and have very little aquatic plant growth. The fishermen seeking bass, sunfish, or pike would want more aquatic plants growth in the lake to provide better habitat for these species.

A. LAKE CONCEPTS

Before describing specific tests which can be performed to determine water quality, it is important that one understand some concepts and definitions relating to lakes. Important aspects to understand are: lake stratification, zones of the aquatic community, aquatic plants;trophic levels; trophic states, properties of hard water lakes, and daily and seasonal cycles.

1. Stratification in Lakes

Water at a given temperature has a certain density. The warmer the temperature of the water, the less dense it becomes. As water becomes colder it becomes more dense and “sinks”. Water reaches its most dense state at 3.94° Centigrade or 39.2° Fahrenheit. Below this temperature, the water becomes less dense again until it freezes, at which time the structure of the water changes to an even less dense crystalline solid. The process of stratification throughout each season is diagrammed in Figure 11.

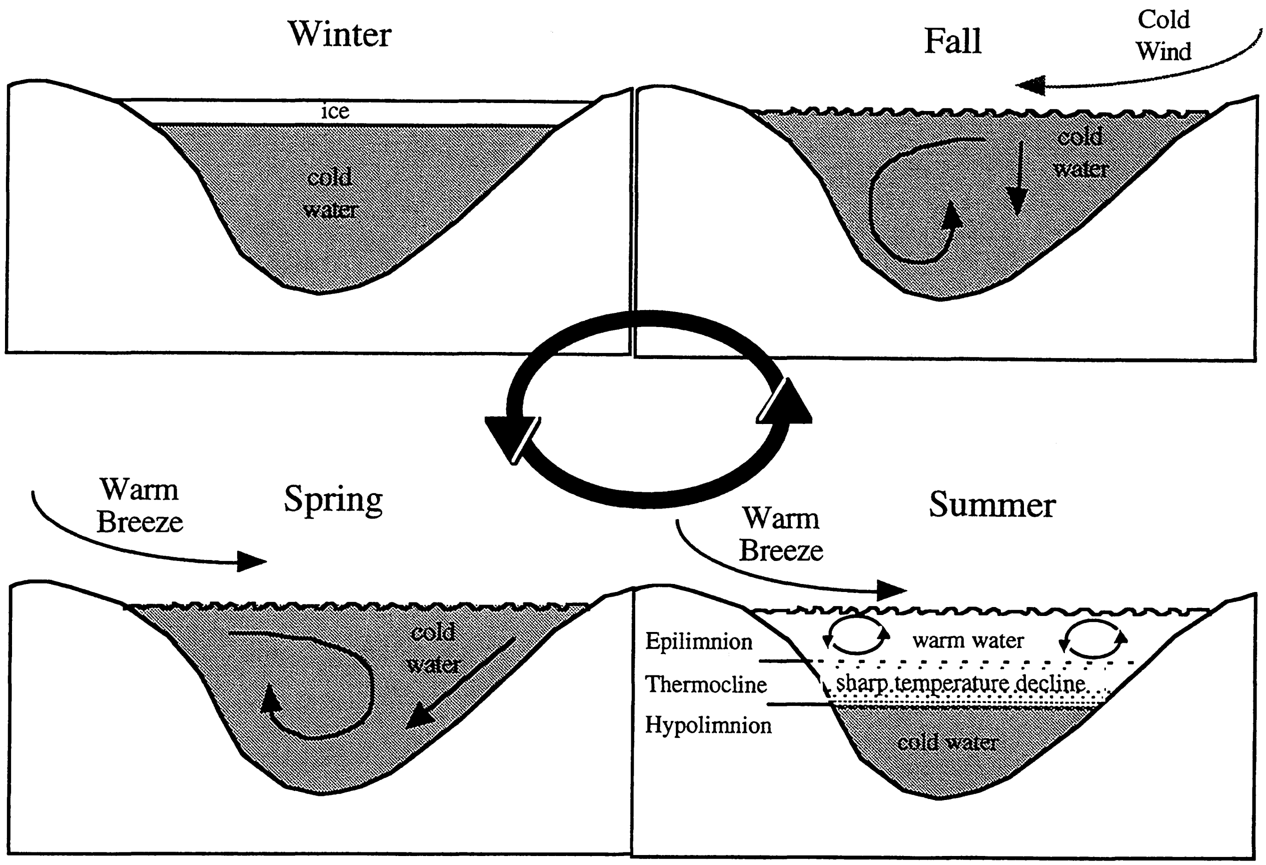


Figure 11: The layering and mixing of lakes during each season.

Winter: In Michigan during the winter months there is a layer of ice on the surface, and underneath is water which is uniformly cold from top to bottom. The water under the ice can become anoxic (depleted of oxygen), when ice prevents atmospheric oxygen from mixing into the water for an extended period.

Spring: As the surface ice melts in the spring, this water warms to 3.94° C and suddenly becomes denser than the colder water below it. This upper water "sinks" forcing the lower water to rise, and the entire lake volume to "turn over". As the water turns over, oxygen is dissolved into the water and mixes throughout the water column. This process is called spring overturn.

Summer: Stratification and summer stagnation refer to the vertical separation or layering of warm and cold water during the summer months. This concept is especially important to the fisherman as it affects wildlife in the lake. As the water warms in the summer, many fish move into the deep, colder water to keep their metabolism low. The health of many organisms, including fish, may decline if the dissolved oxygen level falls too low to sustain their specific requirements.

As air temperatures rise throughout the summer, the surface of the water warms. The warmer surface water in a lake is called the epilimnion. Dissolved oxygen is normally present in relatively high concentrations in the epilimnion. It is absorbed from the atmosphere, and wind and wave action mix it throughout this zone. In addition, algae give off oxygen as a by-product of photosynthesis during the day. The degree of warming at depth is partly determined by wind action, air temperature.

The bottom of the lake remains relatively cold throughout the summer. This zone of water is called the hypolimnion, where denser water sits still at the bottom without mixing with the water above it. Excessive respiration by organisms in the hypolimnion can deplete the oxygen supply, potentially causing these organisms to fall into poor health or suffocate. Between the epilimnion and hypolimnion is a transition zone of water which exhibits a sharp change in temperature. This layer is often called the thermocline.

Fall: During the autumn season when temperatures drop, the epilimnion water cools and begins to sink to the bottom of the lake. Water in the hypolimnion is displaced and forced to rise. This is referred to as fall overturn. Water mixing causes the temperature and dissolved oxygen levels to become uniform throughout the water column. Lime and Little Traverse Lakes are graphed below in Figures 12a through 12d and Figures 13a through 13d to compare water temperature versus dissolved oxygen concentrations at depths during each season.

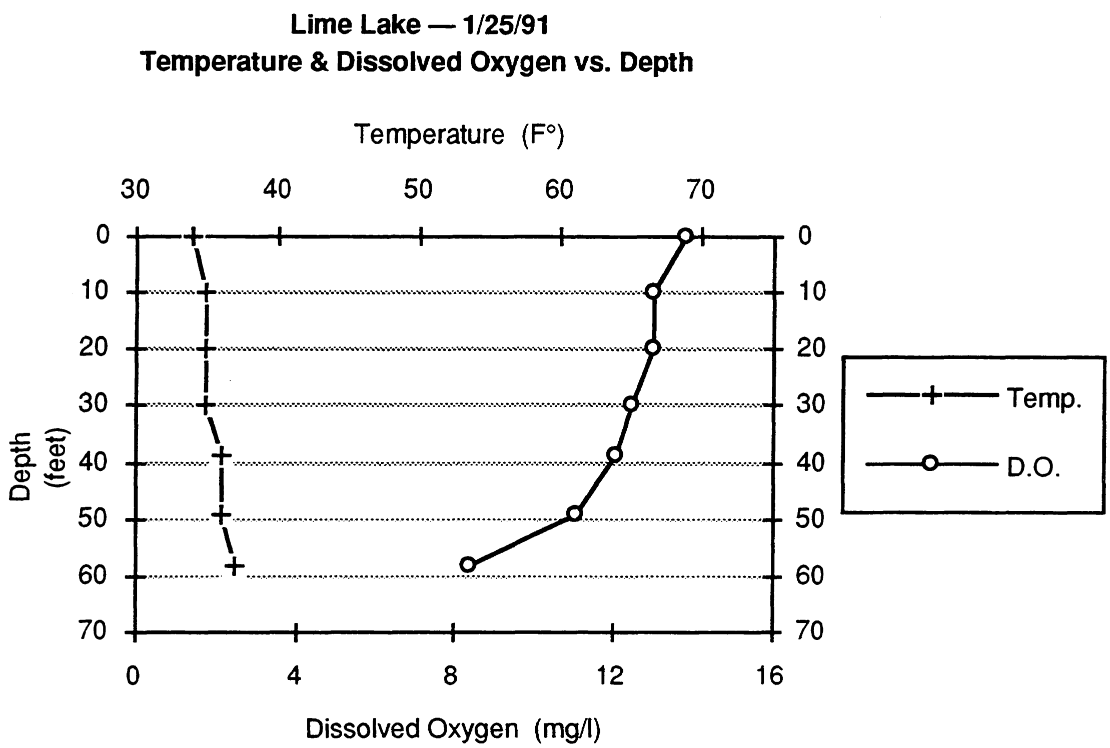


Figure 12a: Lime Lake temperature and dissolved oxygen measurements.

Lime Lake — 4/26/91
Temperature & Dissolved Oxygen vs. Depth

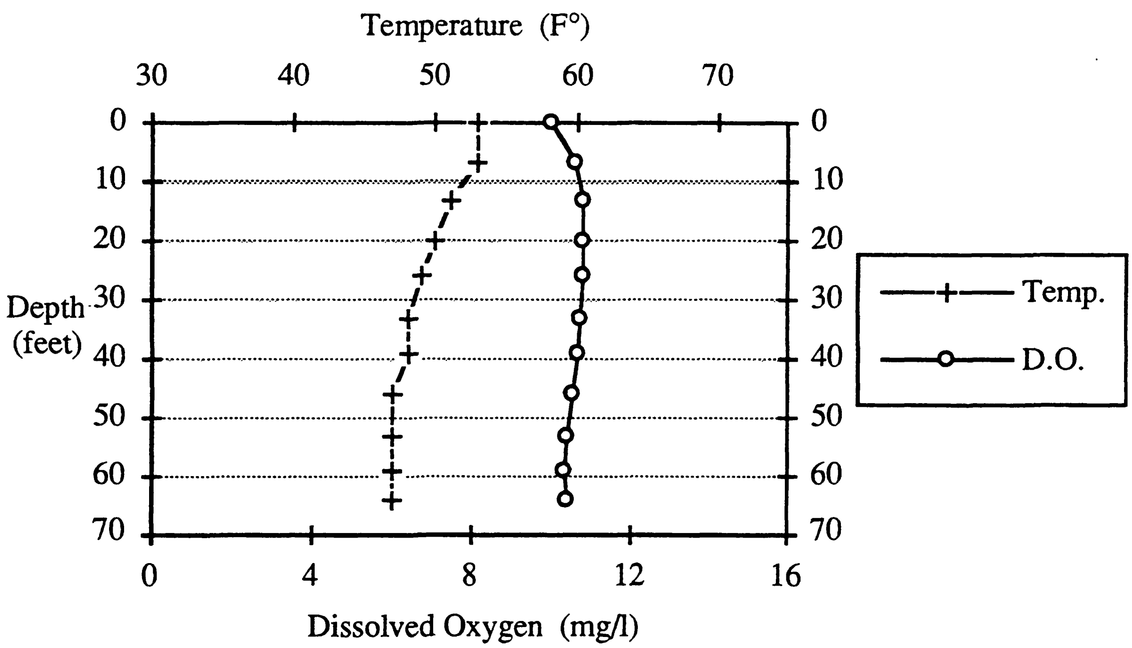


Figure 12b: Lime Lake temperature and dissolved oxygen measurements.

Lime Lake — 8/20/91
Temperature & Dissolved Oxygen vs. Depth

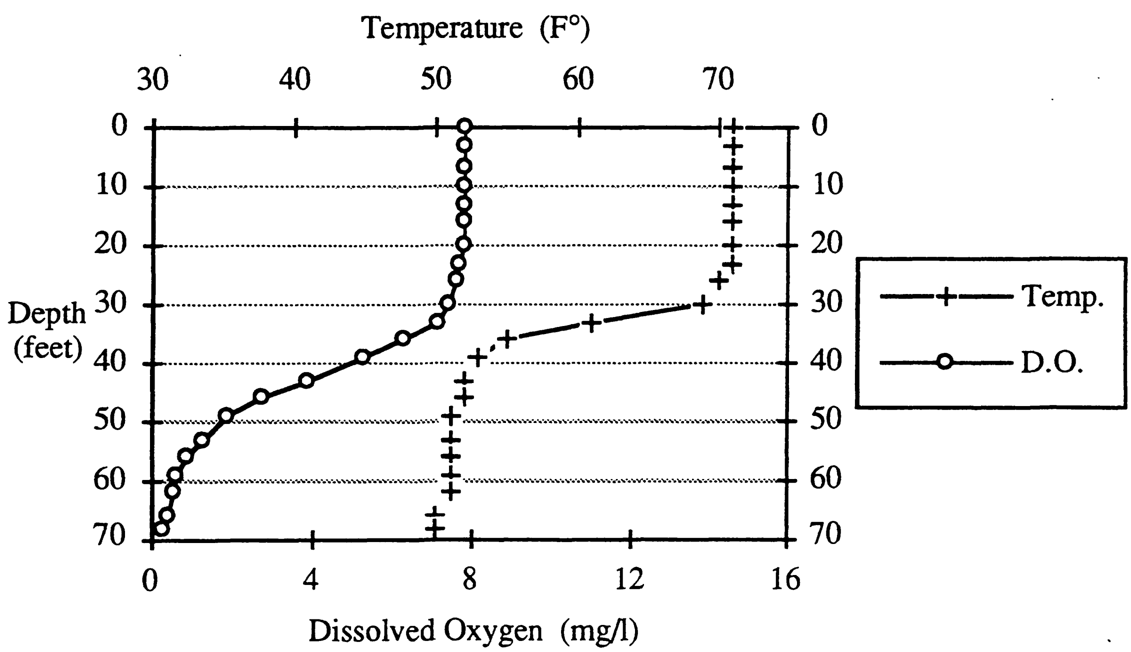


Figure 12c: Lime Lake temperature and dissolved oxygen measurements.

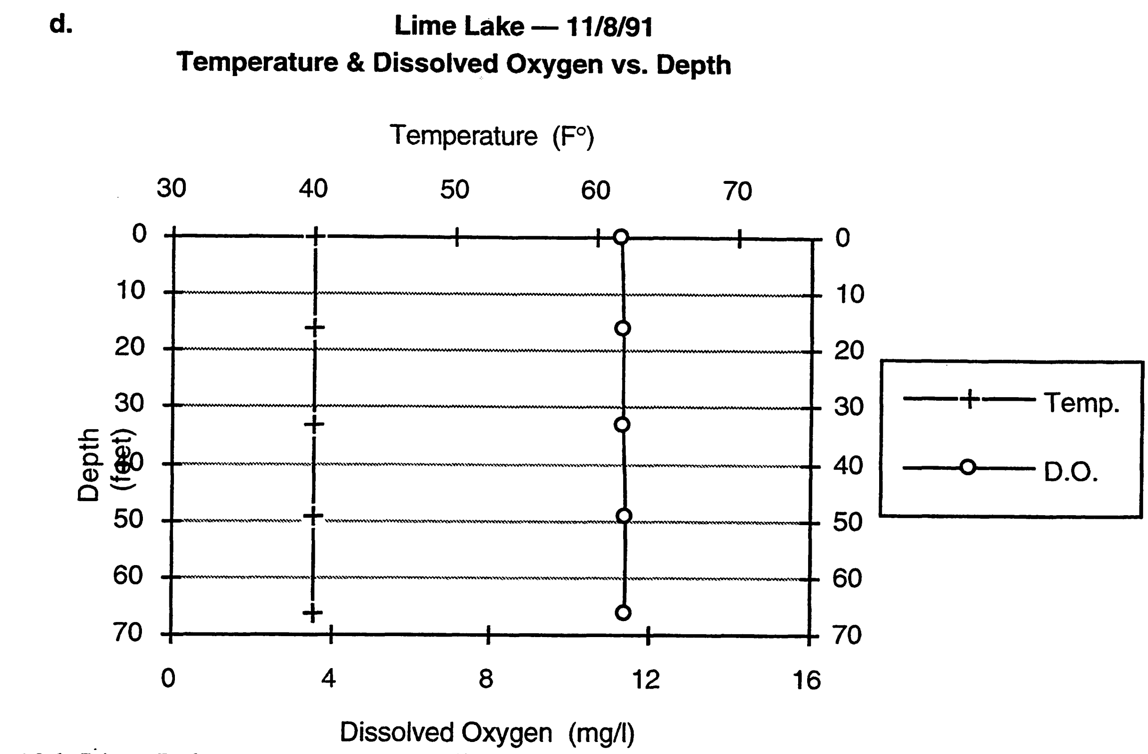


Figure 12d: Lime Lake temperature and dissolved oxygen measurements.

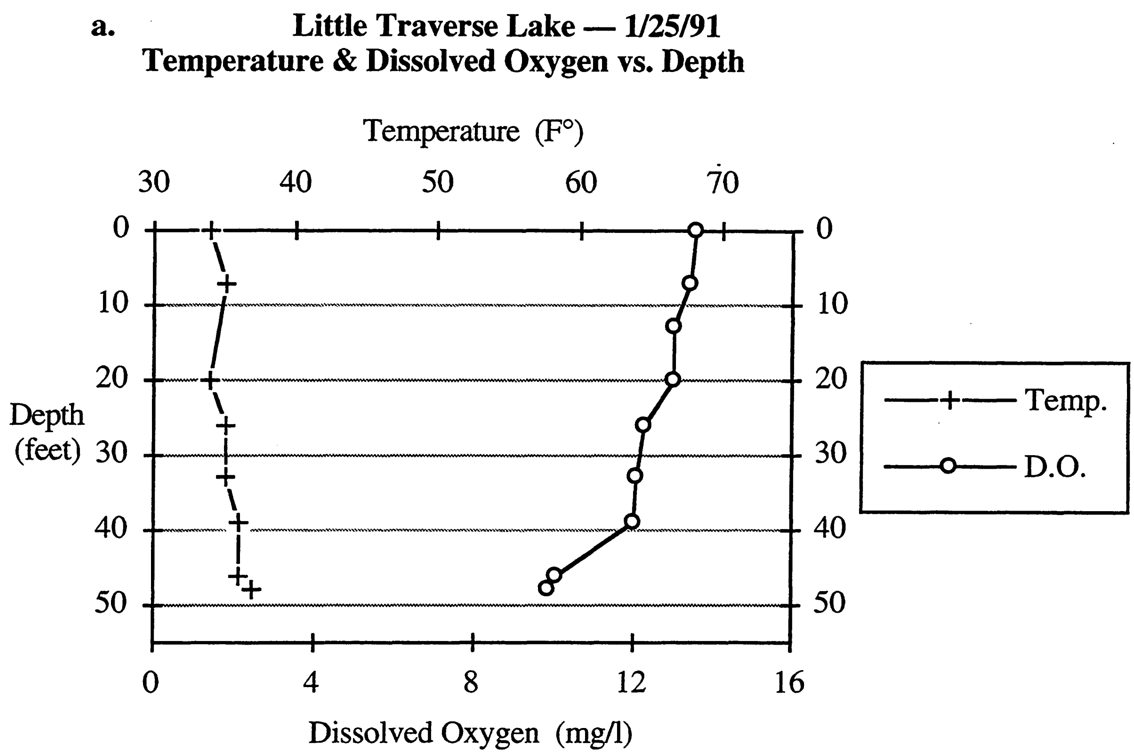


Figure 13a: Little Traverse Lake temperature and dissolved oxygen measurements.

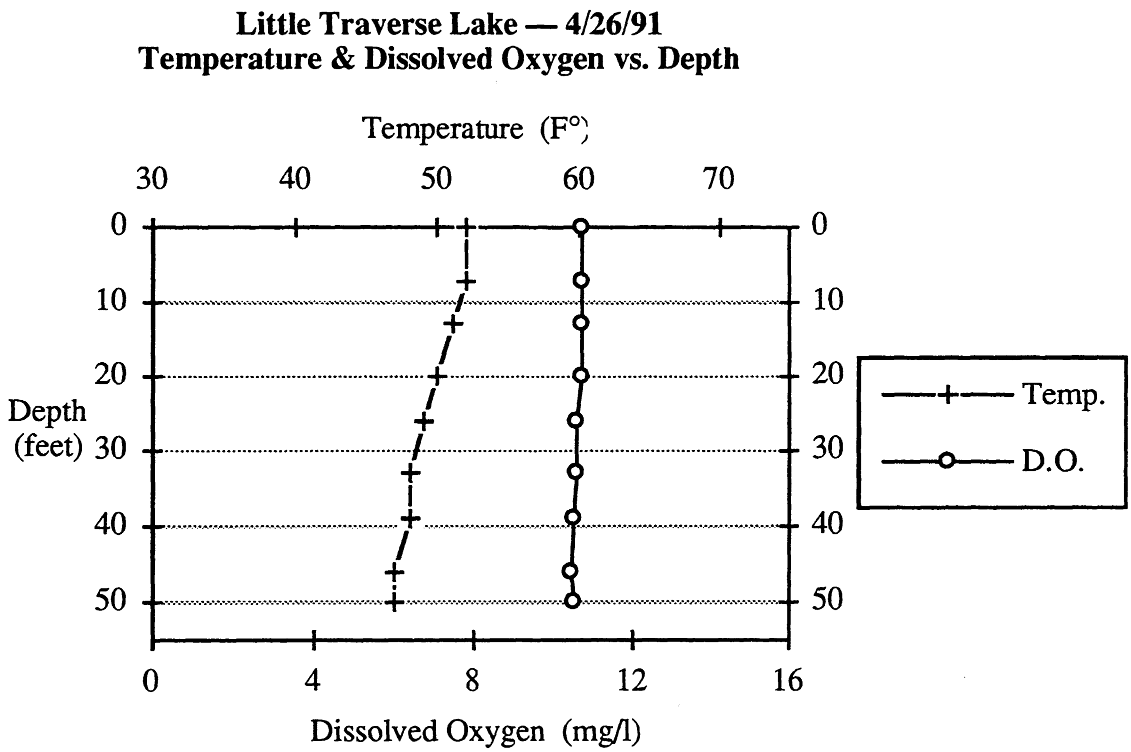


Figure 13b: Little Traverse Lake temperature and dissolved oxygen measurements.

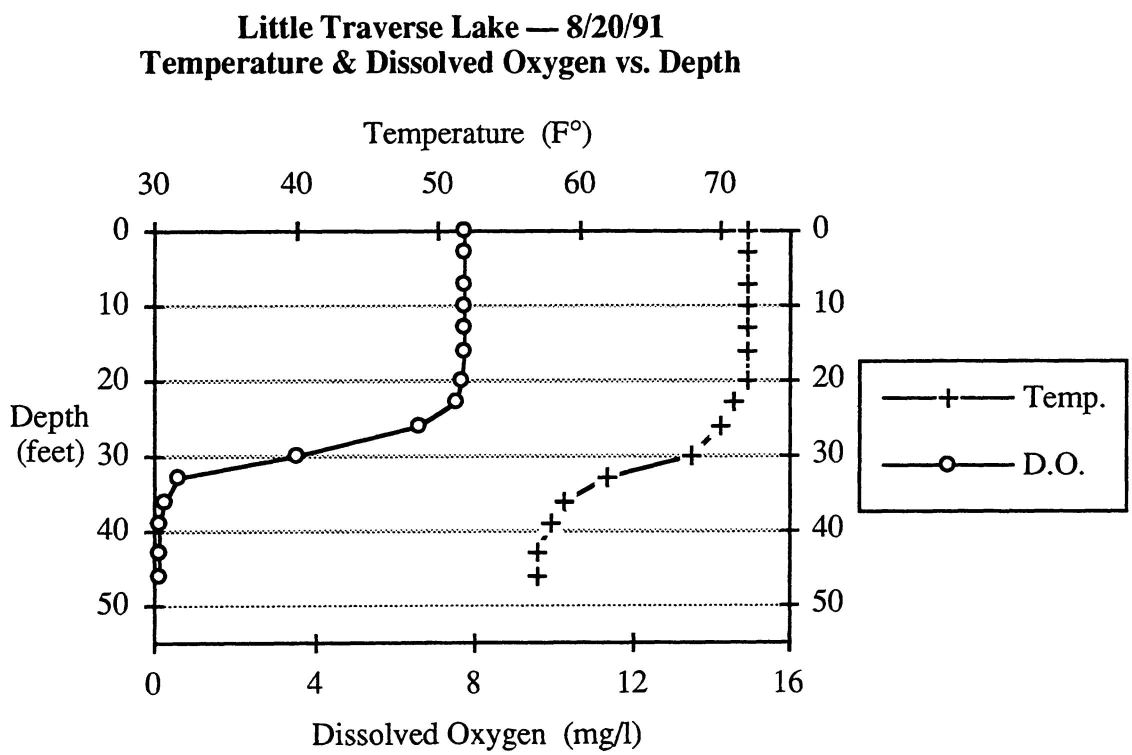


Figure 13c: Little Traverse Lake temperature and dissolved oxygen measurements.

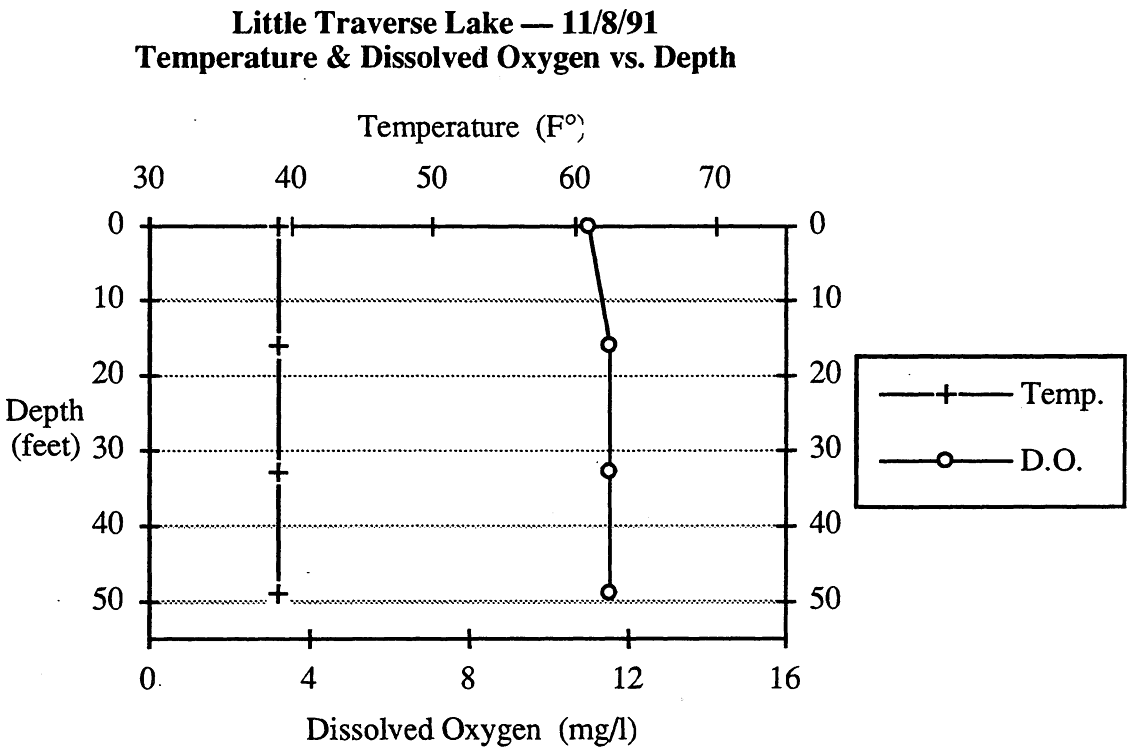


Figure 13d: Little Traverse Lake temperature and dissolved oxygen measurements.

2. Zones of the Aquatic Community

As well as defining lake zones according to temperature, it is also important to define lake zones by the amount of light able to penetrate into the water. Light penetration creates different habitat conditions or zones in which certain organisms can live. This section will explain how the ecosystems function in a lake. These zones are illustrated in Figure 14.

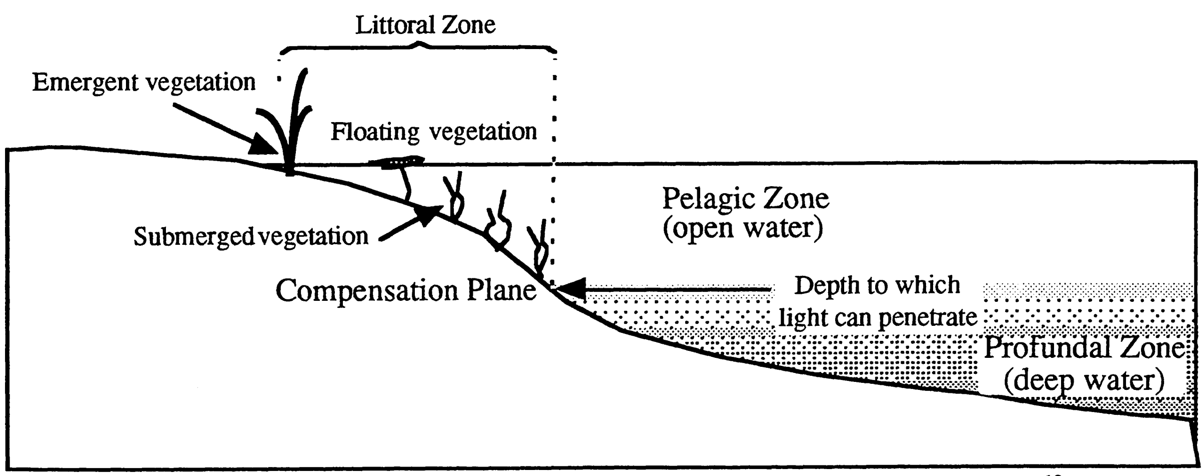


Figure 14: Illustrates the zonation which occurs in lakes in reference to light levels[69].

The depth to which light can penetrate into a body of water is called the compensation plane. The dark water below this plane is called the profundal zone (deep water). The water directly above this is referred to as the pelagic zone (open water). The shallower area of water where light penetrates all the way down to the bottom substrate is called the littoral zone.

Each zone has certain organisms which live there and certain food webs which function within these zones. Fish are often the main predators which overlap all three zones. The littoral zone contains the rooted or attached plant and algae community (macrophytes), as well as most benthic organisms (bottom feeding), and dabbling ducks (feeds from surface of water). The pelagic zone contains plankton, microscopic algae, and many diving waterfowl. The profundal zone contains many deep-water fish, as well as benthic organisms which can survive even at levels of very low dissolved oxygen.

Organisms of the aquatic system can be classified by their feeding habitats and their location in the lake. Benthic organisms are found on the substrate, neuston and pleuston are organisms found at the waters surface, while the other aquatic organisms either swim or float through the water column.

The benthic community includes those organisms which live in or on the substrate of the lake. This includes a wide variety of animals such as worms and clams which burrow into the soil, as well as crayfish, many insect larvae, and snails which crawl on top of the substrate. Most of these are found in the littoral zone. There are many types of tests which use benthic organisms as indicators of water quality, but no testing for benthos has ever occurred on either Lime or Little Traverse Lakes.

Many organisms can be found in the littoral and pelagic zones. Neuston and pleuston are the organisms which live and feed at the surface of the water. Examples include water striders, waterfowl, and many free-floating plants. Free-floating organisms consist mainly of the plankton community. These are microscopic plants and animals which are moved by the currents of the water column more than they are by their own swimming abilities. Phytoplankton normally make up the base of he food web, while zooplankton are the second level in the food-chain.

There are many organisms which must swim to catch their meals. These include many insect, turtles, frogs, and fish. These organisms are normally found in the littoral zone, but many can be found in the pelagic or profundal zones.[53]

3. Macrophyte Community

The term macrophyte refers to all the plants and most of the large macroscopic algae in an aquatic community. These plants can be divided into five groups as follows:

1) Submergent plants which grow completely under water

2) Floating plants rooted in the bottom substrate whose leaves float on the surface of the water.

3) Free-floating plants which float on the surface of the water and whose roots do not grow into the substrate.

4) Emergent plants whose roots are in the substrate below the water level and foliage rise above the surface of the water.

5) Filamentous algae, which are defined as algae visible to the naked eye, and attached to the substrate. These often look like other aquatic plants, but they lack the ability to produce flowers. One common example which was found in both Limė and Little Traverse Lakes is Muskgrass (Chara Spp.).

Macrophytes are important to the lake community for providing shelter and spawning grounds for many aquatic organisms. With some exceptions, most of the plant species are not used as a source of food by the aquatic community. Another function of the plants is to recycle nutrients from the sediment into solution. Phosphorus and other nutrients are absorbed through the roots and are excreted through the leaves or are released when the plant dies.

The amounts and types of macrophytes are dependent on availability of nutrients, carbon, and light. With the exception of the free-floating plants, macrophytes are limited to inhabiting the littoral zone since this is defined as the part of the lake where the sunlight reaches the substrate. The amount of nutrients and carbon will affect the growth of macrophytes.[70]

Oligotrophic lakes produce small quantities of macrophytes, but may have many different species. Light penetrates deep into the clear waters supporting many deep-water submergents. Nutrient levels are scarce so that no single fast growing plant species chokes out other competing species.

Mesotrophic lakes support larger amounts of plant mass than do oligotrophic ones. Light penetration is not as deep due to more planktonic algae, so some deep-water species of submergent macrophytes may be lost. More nutrients are available so plants that do exist produce larger populations.

Eutrophic lakes support the largest amount of macrophyte mass, but only a few species will be represented. Light penetration is low, making it difficult for many of the submergents to survive. Plant and algae species which are adapted to these conditions out-compete and overtake their competitors often creating large weedbeds of a single dominant species.[69]

4. Trophic Levels

There are many ways to illustrate a food chain for aquatic systems. Some examples are food pyramids, food webs, food chains, and trophic levels. Food pyramids and food chains are too simplified, while food webs can be overwhelming to read. The most accurate and readable way to explain the predator/prey relationship of aquatic ecosystems is through the trophic levels as adapted from W.D. Russell-Hunter.[52] All of the organisms are divided into five different trophic levels based upon the type(s) of food they eat or produce. See Figure 15.

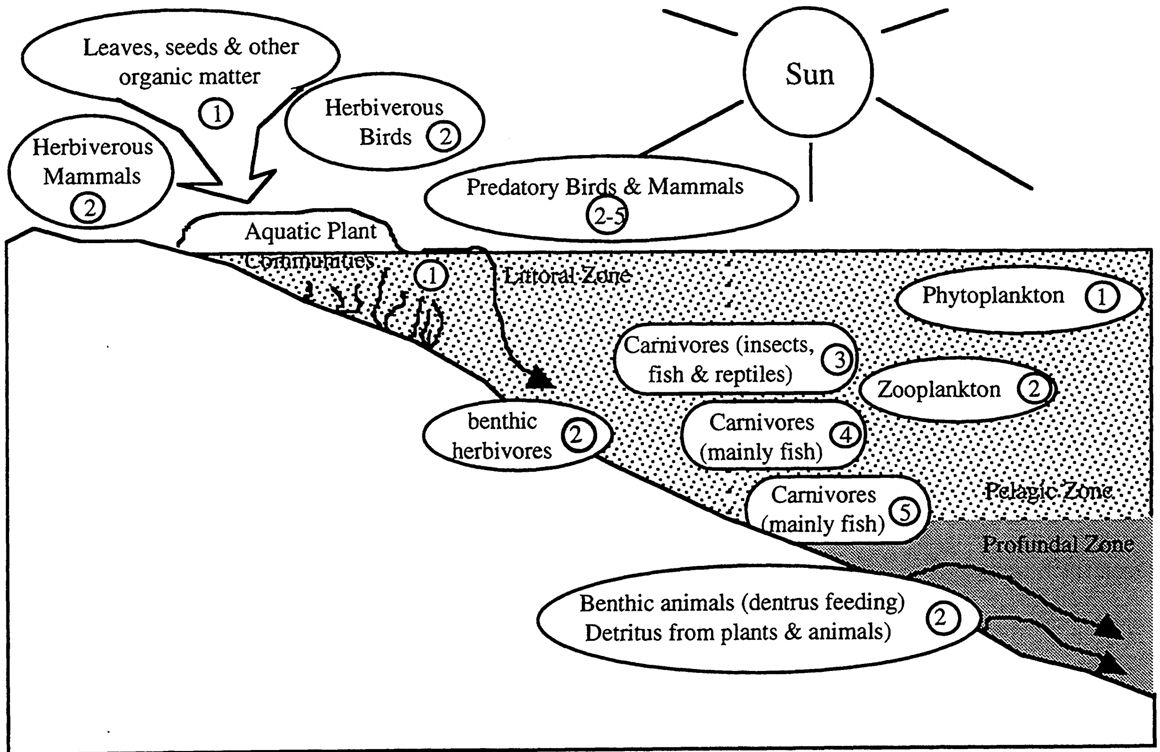


Figure 15: The trophic levels and the zone(s) in which the organisms are normally found.[52]

Trophic level 1 includes the food producers. This includes all of the plants, algae, and other phytoplankton which make up the bottom of the food chain. Trophic level 2 includes the organisms which directly feed on the producers. This includes the zooplankton, herbivores, and detritus feeding organisms. Trophic level 3 includes the animals which feed on the level below it. This may include many small fish, certain insect larvae, and many other organisms. Trophic level 4 includes mainly fish, certain birds, and certain mammals, all of which are usually carnivores. Trophic level 5 includes the top of the food chain. This would include such things like full grown pike, bass, and mergansers.

Complicating the neatness of this illustration is the fact that many of the organisms can fit into many trophic levels. A young fish may be on a trophic level beneath an insect larvae, but will prey on that same insect larvae when size permits. For example the small mouth bass often falls prey to the dragonfly nymph, but will prey on that nymph if it gets older. When large enough, it will prey on the prey of that nymph.[52]

5. Trophic Status — Lake Clarity and Productivity

Trophic state refers to the amount of algal growth in a lake. In general, lakes with large concentrations of algae are less clear than lakes with very little algae. The classification system used in Michigan to identify trophic states in the Carlson's Trophic State Index (TSI). Relative rating of biological productivity is the main purpose of this categorization. It takes into account such factors as; water transparency, organic matter content, and nutrient levels.[42]

Planktonic algae in the water makes visibility into lake depths more difficult. Algae is important for all of the users of the lake since too much algae will make the waters less clear for swimmers, and decaying algae in the summer could deplete the oxygen supply, resulting in anoxic conditions in the hypolimnion.

TSI classification categorizes the lakes by their physical, chemical, and biological characteristics into one of three categories: oligotrophic, mesotrophic, or eutrophic. Oligotrophic lakes are ones where the algal productivity is low, there is little phosphorus dissolved in the water, and the water is clear. Eutrophic is the other extreme where there is a great deal of algal productivity, there are high amounts of phosphorus in the water, and the clarity of the water is low. Mesotrophic is the median of these two. This is discussed below in detail under the heading Tests and Testing— Trophic State Index from Secchi, Phosphorus, Chlorophyll *a*.

6. Hard-water Lakes

Both Lime and Little Traverse Lakes are considered hard-water lakes. Such lakes contain large amounts of calcium (Ca) and magnesium (Mg), and are associated with carbonates (CO3). These lakes are surrounded by calcareous soils, which are eroded into the lake from the watershed.[69] Calcareous soils contain large amounts of calcium, magnesium, potassium, and sodium, which are considered bases.

Marl ($CaCO_3$ or $MgCO_3$) is produced when calcium and/or magnesium combine with carbonate. This compound has the ability to adsorb many nutrients and certain types of organic compounds. This process limits algal growth by precipitating many of the nutrients required for their growth to the bottom sediments. Phosphorus, iron, manganese, and other elements are prone to form heavy compounds in marl lakes which sink to the substrate.[69]

The availability of potassium and sodium is generally low in marl lakes, while nitrogen levels may be exceedingly high. The prevalence of nitrogen is due to its abundance in many calcareous soils, and also due to the lack of macrophytes and phytoplankton to take it out of solution.[69]

Hard-water lakes are resistant to eutrophication, due to the lack of organic materials being produced in the waters. As sources of calcium, magnesium, and bicarbonates are depleted, this process may proceed rapidly, conducive to bog formation.[69]

7. Distinguishing Trends from Cycles

Lake organisms go through daily and yearly cycles. It is important to distinguish cycles from longer term trends when monitoring water quality. This can effect the time of day when tests should be taken and it is important to be able to realize when trends are occurring and when there not. Cycles are daily, seasonal, or yearly changes in organisms in relationship to their life cycle. Trends are long term changes in organisms over many years.

Examples of a daily cycle are certain zooplankton and algae which are suspended high in the water column during the day to feed, but drop deeper in the water at night to avoid predators.

A yearly cycle could refer to the prevalence of certain algae when spring overturn occurs, but reducing populations as the summer progresses due to limited availability of phosphorus, and/or other nutrients. Another yearly cycle is migration of fish populations. Many fish inhabit shallow water during the spring to spawn. When the water temperatures warm, many must migrate to deep waters to live.

Trends occur when cycles consistently change in a way that becomes a predictable pattern over a longer period of time. For example, one year of unusually high spring algal blooms is not a trend. Several years of higher blooms may or may not signal the start of a long term trend. If year after year the blooms generally are larger than the previous year, then a long term trend is occurring. Many years of data are required to identify trends.

It can be tricky to monitor water quality without knowing the cycles which occur within the lake. Often test samples should be collected at certain times of the day to obtain an accurate reading. One example is the chlorophyll *a* test, which measures the amount of a specific type of chlorophyll, mostly algae, found in the water column. Early morning samples collected at the surface may show no chlorophyll *a* due to a nighttime migration of the algae to a lower plane in the water column, while during mid-afternoon the numbers are greatest. Dissolved oxygen and secchi disc values can also show skewed results due to the time of day.

B. TESTS AND TESTING

Testing has been done on Lime and Little Traverse Lakes for a relatively short period of time. The earliest tests were performed in 1947 and 1949, with a long gap until 1970.

It should be determined which testing procedures are most applicable to these lakes. The specific types of tests included in this discussion include most of the tests done in the past and present, and other common tests which could be considered.

Testing procedures by the Institute for Fisheries Research and the MDNR were not researched for this discussion, but appear to have been done scientifically and accurately. Most of the testing by the Leelanau Conservancy has been done using a "Hydrolab". This is not considered scientifically accurate, but it produces very close results. This piece of equipment measures depth, temperature, dissolved oxygen, pH, conductivity, and Oxidation Reduction Potential (ORP).[28] This equipment is calibrated as instructed by the manufacturer, and often post-calibrated after sampling. Nitrates and nitrites, and total phosphorus samples are tested by the Great Lakes Environmental Laboratory in Traverse City, Michigan, and stream sampling data was tested by the MDNR at the DNR Environmental Laboratory in Lansing.[29] Chlorophyll *a* was tested for by the Leelanau Conservancy in 1993, and it is unknown who produced the results. In addition to these tests, the Leelanau Conservancy also tests Secchi Disk depth.[28]

1. Measures to Determine Water Quality

There are many tests to measure various aspects of water quality. One objective of this study was to determine the most appropriate measures for the Leelanau Conservancy to monitor the quality of the lakes. The methodology of the Leelanau Conservancies data collection deserves careful analysis and substantiation.

The current goals of the Conservancy are to establish a base of data over time which will monitor the quality of the lakes, as well as to create a nutrient budget for each of the major lakes in Leelanau County. Trophic status is determined by secchi disc values, total phosphorus, and now with chlorophyll *a*.

A nutrient budget is a measure of the nitrogen and phosphorus inputs into a lake, and a measure of the outputs of these nutrients. From these data the amount of phosphorus which is allowable into a lake without accelerating eutrophication can be determined.

Other ways to determine the quality of water will be discussed as possible alternatives or additions to the current testing of the lakes.

One of these methods is a scoring system using a single number to grade a lake, as developed by Dr. Wallance Fusilier. This system was established by surveying 555 limnologists to determine the nine tests which they deemed to be the most important to measure water quality. These tests include: Temperature in degrees Centigrade, dissolved oxygen percent saturation, chlorophyll *a* in mg/m3, secchi disc depth, nitrate nitrogen in μg/l, pH, specific conductivity in umhos/cm at 25°C, and total phosphate phosphorus in μg/l. The result of each test is rated on a scale of 1 to 100, and these tests are multiplied together and the 9th root is taken to give a single number which ranges from 1 to 100. The final score provides a useful index of water quality.[20]

There are many other parameters used to measure water quality. Table 4 shows the relationship used to determine the quality of water for drinking and recreational activities, while table 5 indicates the best parameters for most fish species. Table 6 indicate the specific dissolved oxygen and pH ranges for more specific types of organisms.

Table 4: Parameters for drinking water and recreational activities set by the Environmental Protection Agency (EPA) and the MDNR.[23,42]

	Drinking Water		Full body Contact Recreation
	Permissible Standards	Desirable Standards	
Coliform organisms	10,000/100 ml	<100/100 ml	Mean of 1000 with no more than 10% of samples exceeding 2000
Fecal coliforms	2,000/100 ml	<20/100 ml	Mean of 200 with no more than 10% of samples exceeding 400
Ammonia	0.5 mg/l (as N)	<0.01 mg/l	
Lead	0.05 mg/l	Absent	
Nitrates + nitrites	10 mg/l as (N)	Virtually absent	
pH range	6.0 to 8.5	Variable	
Toxaphene	0.005 mg/l	Absent	
Methoxyclor	0.1 mg/l	Absent	
Lindane	0.1 mg/l	Absent	
Endrin	0.0002 mg/l	Absent	
2,4-D	0.1 mg/l	Absent	
2,4,5-TP	0.01 mg/l	Absent	
Minimum Dissolved Oxygen (ppm)	4.0		4.0 to 5.0
Dissolved Solids (mg/l)	500 to 750		Absent
Other Solids (mg/l)	No floating solids or Settleable Solids which form deposits		No floating solids or Settleable Solids which form deposits
Chlorides (mg/l)	Not to exceed 125 monthly average		

Table 5: Parameters of many common tests which indicate a healthy ecosystem for most species.[23,42]

	Parameters good for most fish and wildlife
Dissolved Oxygen (mg/l or ppm)	≥5
pH (Range)	6.5 to 9.0
Temperature	≤20 to 30° Centigrade (68 to 86° Farenheight) depending on species and acclimation
Nutrients	≤the amount needed to stimulate aquatic plant, bacteria, or fungi growth
Hardness (mg/l)	20 to 150
Alkalinity as $CaCO_3$ (mg/l)	≥20
Total dissolved solids (mg/l)	Usually positively correlated with productivity
Other solids	No floating or settleable solids which form deposits
Turbidity, color, oil films, foams, deposits, solids (floating, suspended, or settleable)	Unnatural quantities shall not be injurious to a specific use (such as fishing)
Taste and odor	Not to impair the palatability of fish
Maximum allowable total coliform (/100 ml)	Mean of 5000

Table 6: The temperature and pH requirements for many types of organisms.[43]

	Temperature	pH
Many warm-water fish diseases	> 20° Centigrade (68° Farenheight)	
Many macrophytes and some diseases of fish	13 to 20° Centigrade (55 to 68° Farenheight)	
Trout, stonefly and mayfly nymphs, and caddisfly larvae	> 20° Centigrade (68° Farenheight). 13 to 20° Centigrade (55 to 68° Farenheight)	6.5 to 7.5
Water beetles	13 to 20° Centigrade (55 to 68° F)	
Bacteria		1 to 13
Most macrophytes	20° Centigrade (68° Farenheight)	6.5 to 12
Benthic warm-water fish (Carp, suckers, and catfish)		6 to 9
Many insects		6 to 9
Bass, crappies, and bluegill		6.5 to 8.5
Snails, clams, and mussels		7 to 9

The state of Michigan has set certain parameters for lakes to be considered swimmable and fishable, consistent with the Federal Clean Water Act (CWA). The CWA defines fishable as the protection and propagation of fish, shellfish, and wildlife. Swimmable is defined as providing for recreation in, or on, the water.[42]

a. Dissolved Oxygen and Temperature

Nearly all aquatic organisms need Oxygen to survive. There are two ways for Oxygen to become available in the water: 1) Gasses are absorbed into water from the atmosphere, and; 2) Plant photosynthesis produces and releases oxygen into the water. In eutrophic lakes it is possible to have excess levels of Dissolved Oxygen (DO) during the day and be well below safe levels at night when the plants, animals, and bacteria take up oxygen for respiration. Coldwater fish (such as trout and salmon) require dissolved oxygen levels greater than 5 mg/l to survive. If levels fall below the safe level for an aquatic species, the population may potentially fall into poor health or die.

Temperature is an important lake measurement, relating to both stratification and DO concentration. Cold water is generally capable of holding more dissolved oxygen than warmer water. The metabolism of many organisms have been adapted to certain temperatures. During the summer months many of the larger fish species move to the deep colder waters. If the DO is depleted from these zones the fish may die. All testing on Lime and Little Traverse Lakes has included both temperature and DO. Results show both lakes are completely stratified by mid-August. DO concentrations fall below the safe levels for many fish in the hypolimnion. The two lakes are similar in temperature and DO levels, although Little Traverse Lake appears to become anoxic sooner and slightly more severely than Lime Lake.

Using the following figures in this section, comparisons are made in two ways:

1) Using the data throughout the years of 1990 to 1992, seasonal cycles can be determined. Factors which are investigated by this project group include the time of turnover, depletion of DO from the hypolimnion, and timing algal bloom occurrences. Testing was done at approximately the same dates during the summer and fall making the comparisons relatively easy. But more sporadic testing during the winter and spring months makes comparisons somewhat more complicated.

2) The second set of comparisons is between similar dates over multiple years, to detect trends.

Comparing the data from the three full years 1990-1992 shows the approximate time of fall overturn, algal blooms, and stratification. Only in 1991 were there ample test dates to show the spring overturn. In 1990, testing did not begin until May 21, which was after the spring overturn. There is no way to tell how much depletion of DO had occurred under the ice. Testing ceased on October 25 before the formation of the ice. The 1992 data shows a long gap in testing between March 10 and May 6. Ice was still on the lakes March 10. In the previous year we know that spring overturn had occurred by April 26. In all years a thermocline has already begun to form by May. Since the timing of the testing was the best in 1991, the following discussion is based on the changes throughout that particular year. Comparisons with the other years are mentioned if they differ significantly from 1991.

The first test of Lime Lake on January 25, 1991 is represented in Figures 16a through 16h.

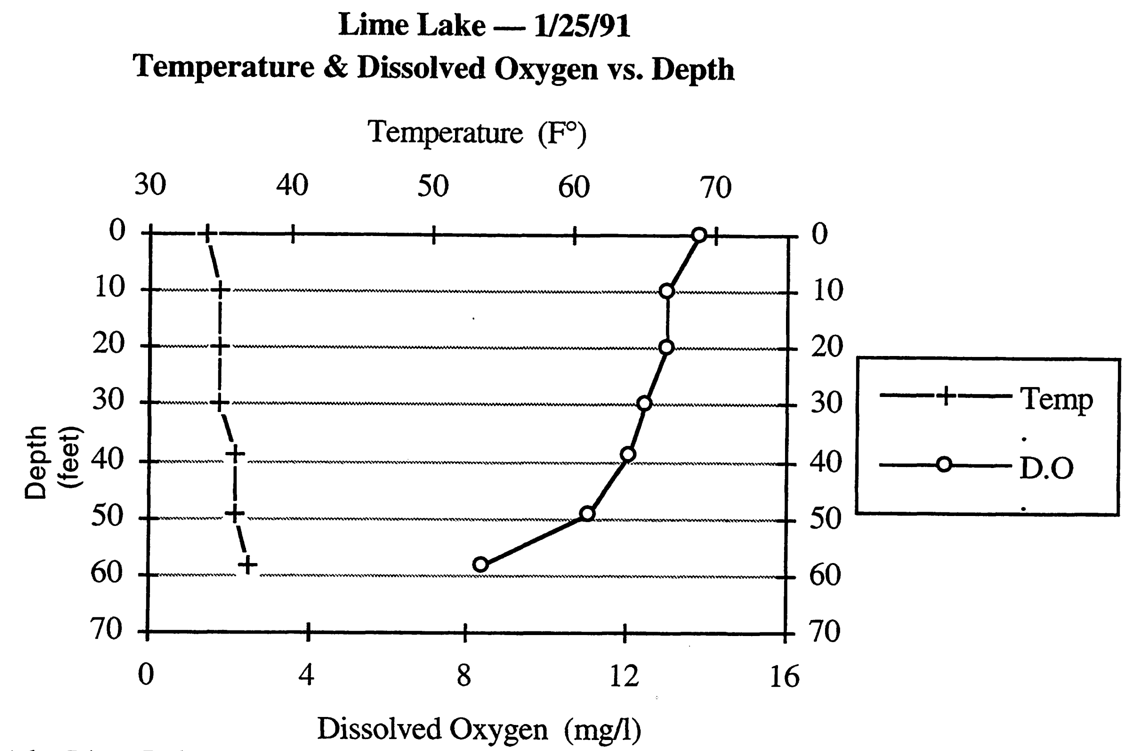


Figure 16a: Lime Lake temperature and dissolved oxygen measurements.

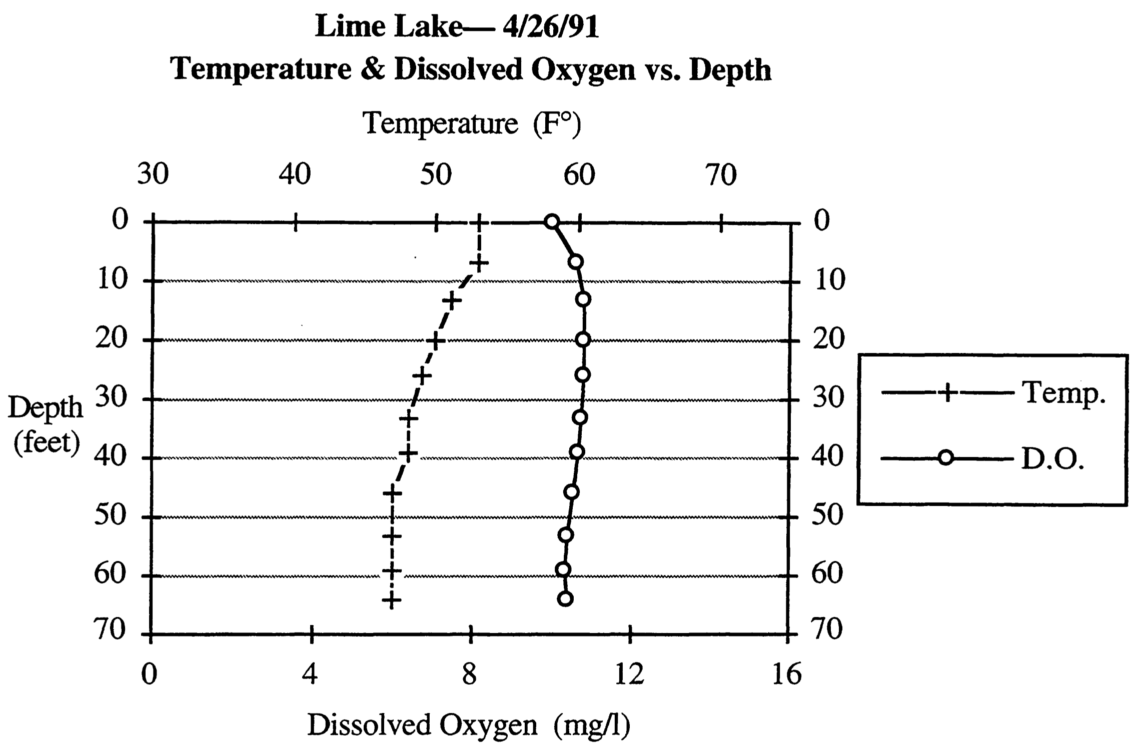


Figure 16b: Lime Lake temperature and dissolved oxygen measurements.

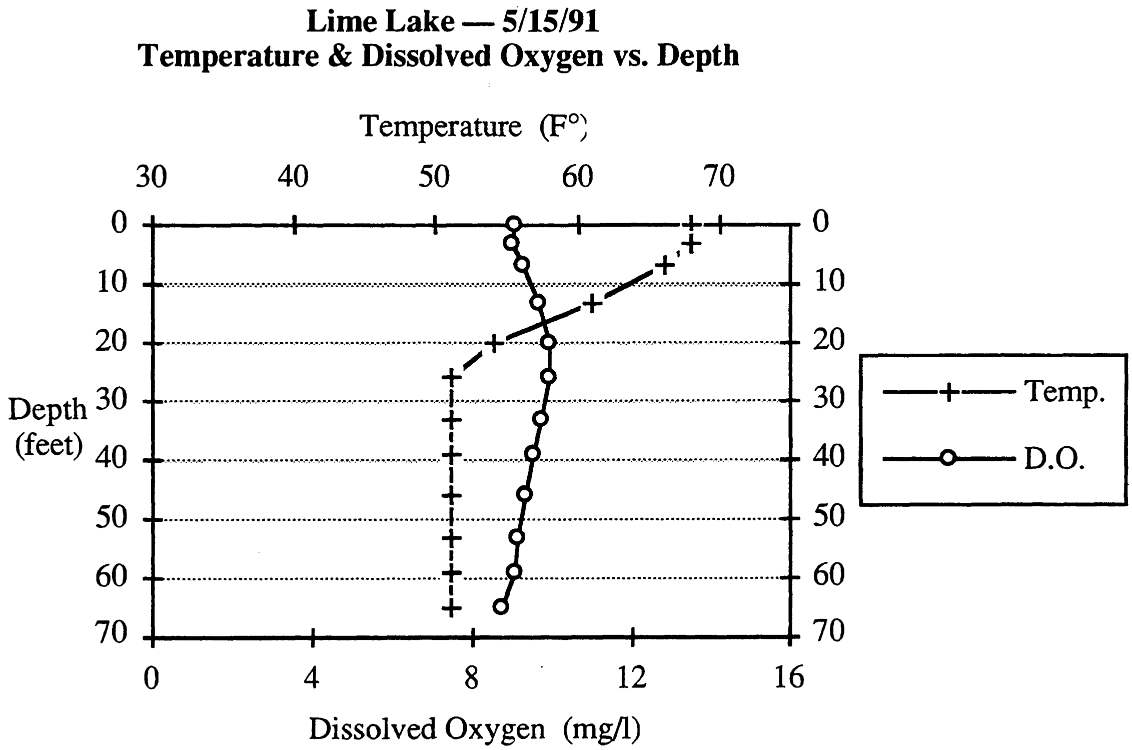


Figure 16c: Lime Lake temperature and dissolved oxygen measurements.

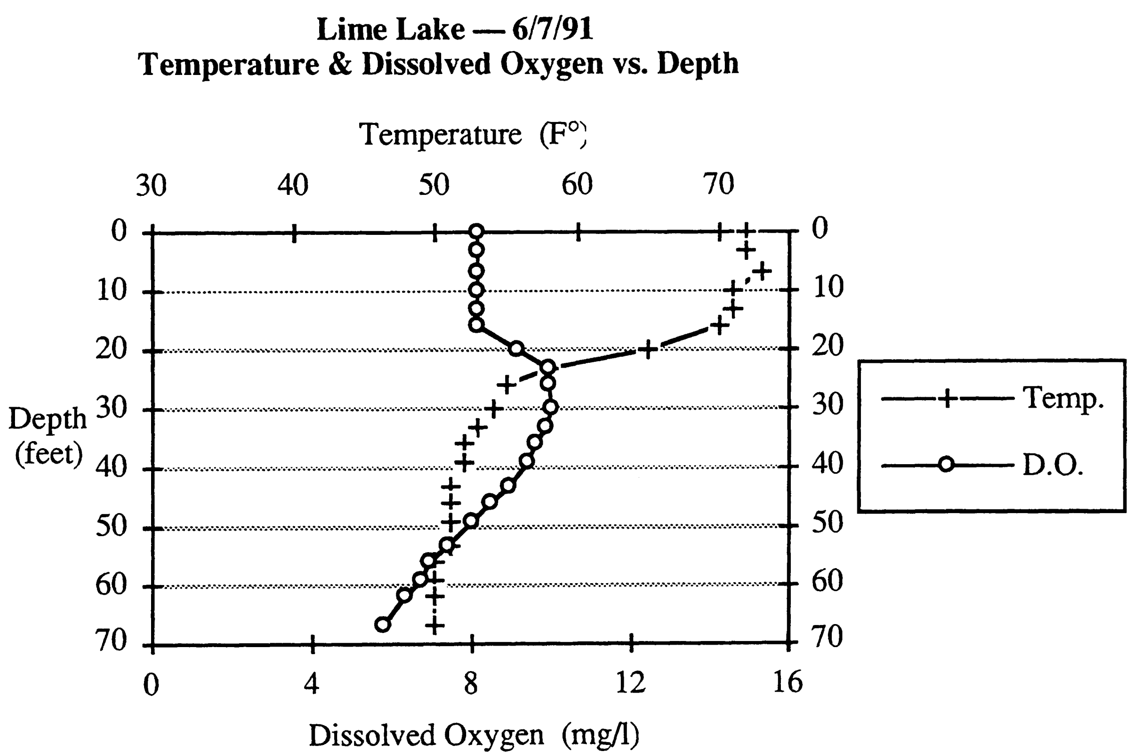


Figure 16d: Lime Lake temperature and dissolved oxygen measurements.

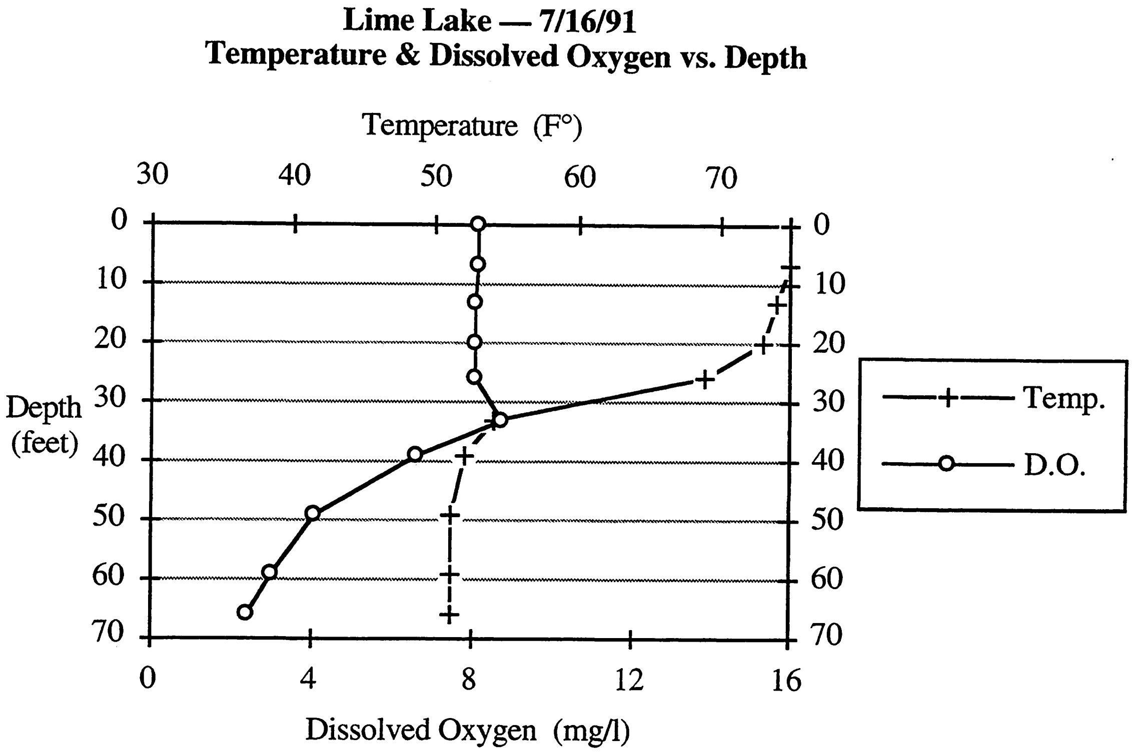


Figure 16e: Lime Lake temperature and dissolved oxygen measurements.

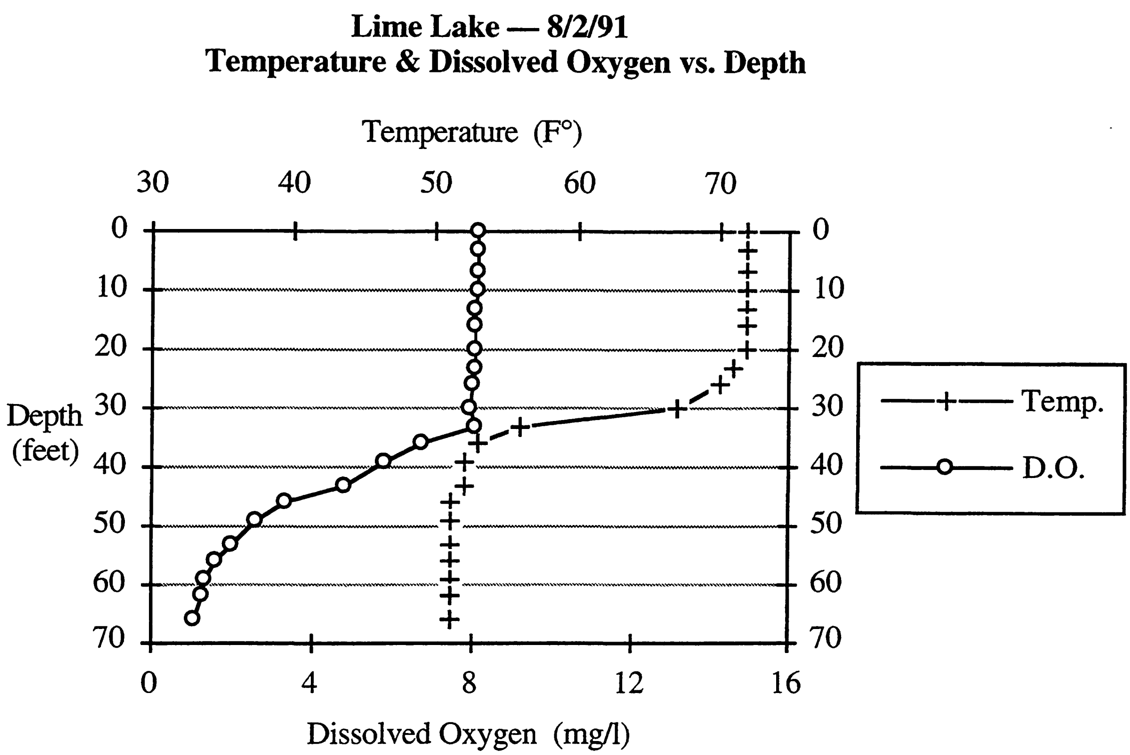


Figure 16f: Lime Lake temperature and dissolved oxygen measurements.

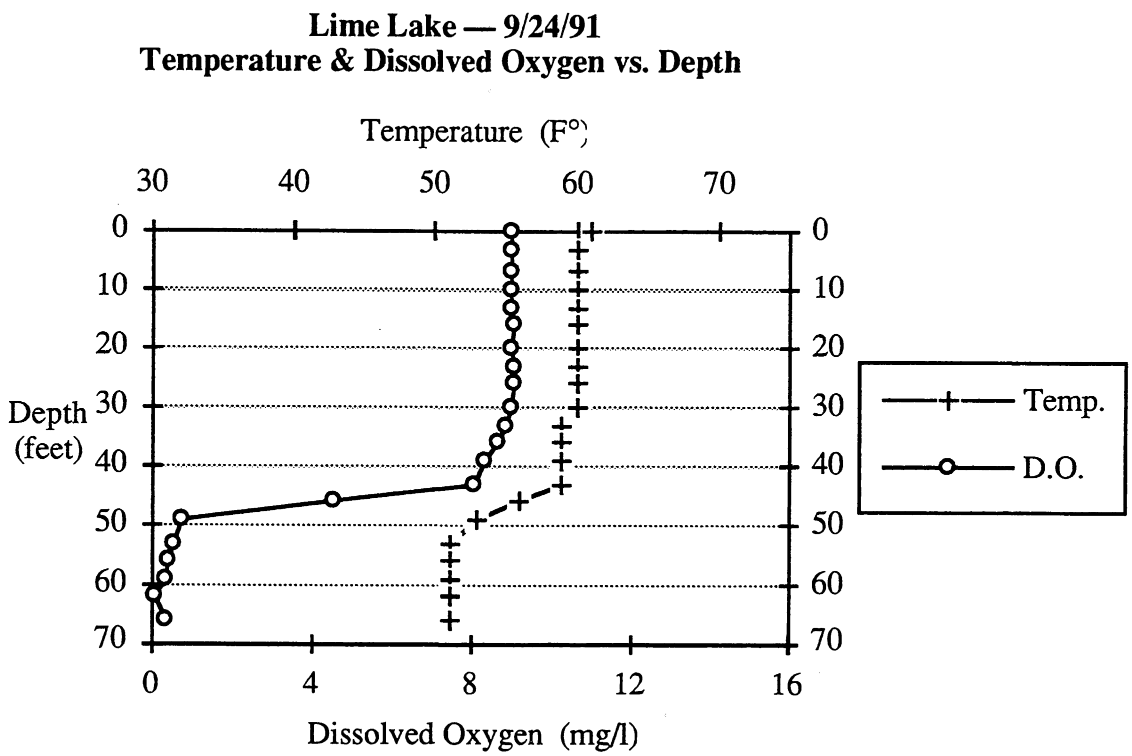


Figure 16g: Lime Lake temperature and dissolved oxygen measurements.

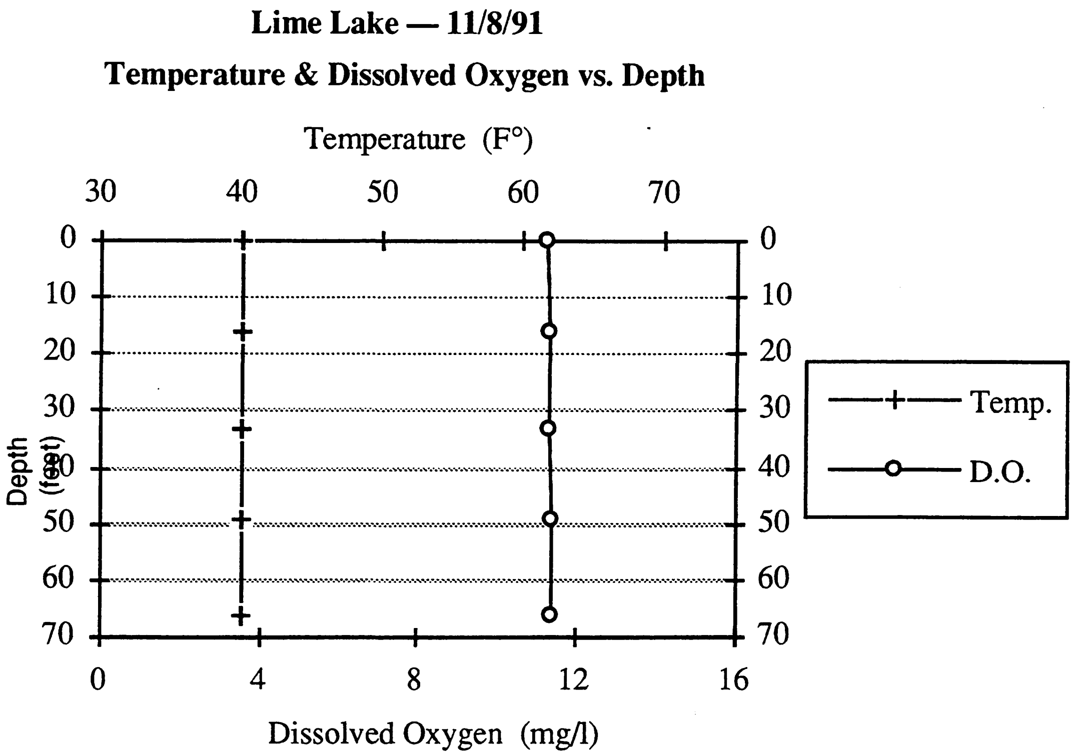


Figure 16h: Lime Lake temperature and dissolved oxygen measurements.

The high DO levels throughout the water column were quite good for aquatic life, with slightly lower levels at the bottom. By April 26 spring overturn had already occurred, evidenced by the uniformity of temperature and DO throughout the water column. On May 15 the thermocline was forming between five feet and twenty five feet. The DO graph bulges horizontally at most depths, indicating that perhaps algae was consuming DO throughout most of the water column. Between June 7 and July 16 the thermocline was moving deeper into the water and the algal bloom was becoming more compact or localized in depth. By August 2 the algal bloom had disappeared. DO levels had fallen too low to support any trout population, and the thermocline had moved to a depth of thirty feet to thirty five feet. On September 24 the DO was almost depleted from the hypolimnion. The fall overturn probably occurred soon after this, as the surface temperature had fallen dramatically to nearly the same temperature as the rest of the water column. The next test on November 8 1991 was well after the overturn had occurred.

In 1992, Figure 17a shows an unexplained sag in the DO levels on August 8 between ten and fifteen feet. Figure 17b shows fall overturn was occurring September 23,1992.

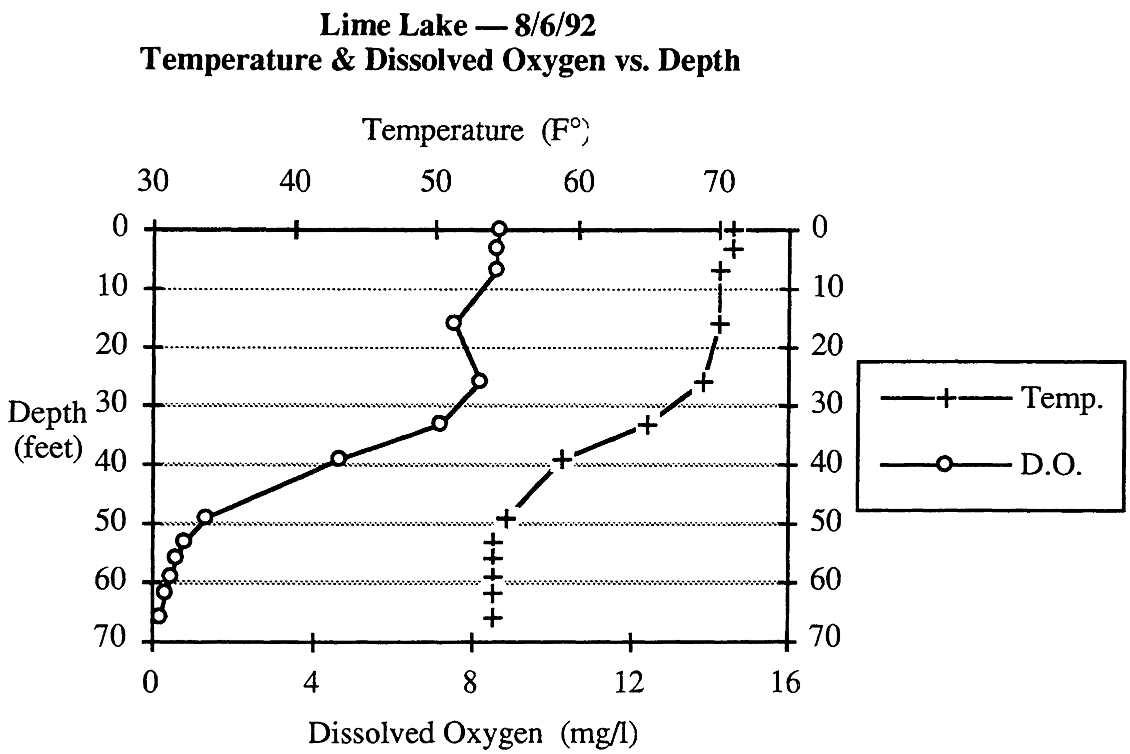


Figure 17a: Lime Lake temperature and dissolved oxygen measurements.

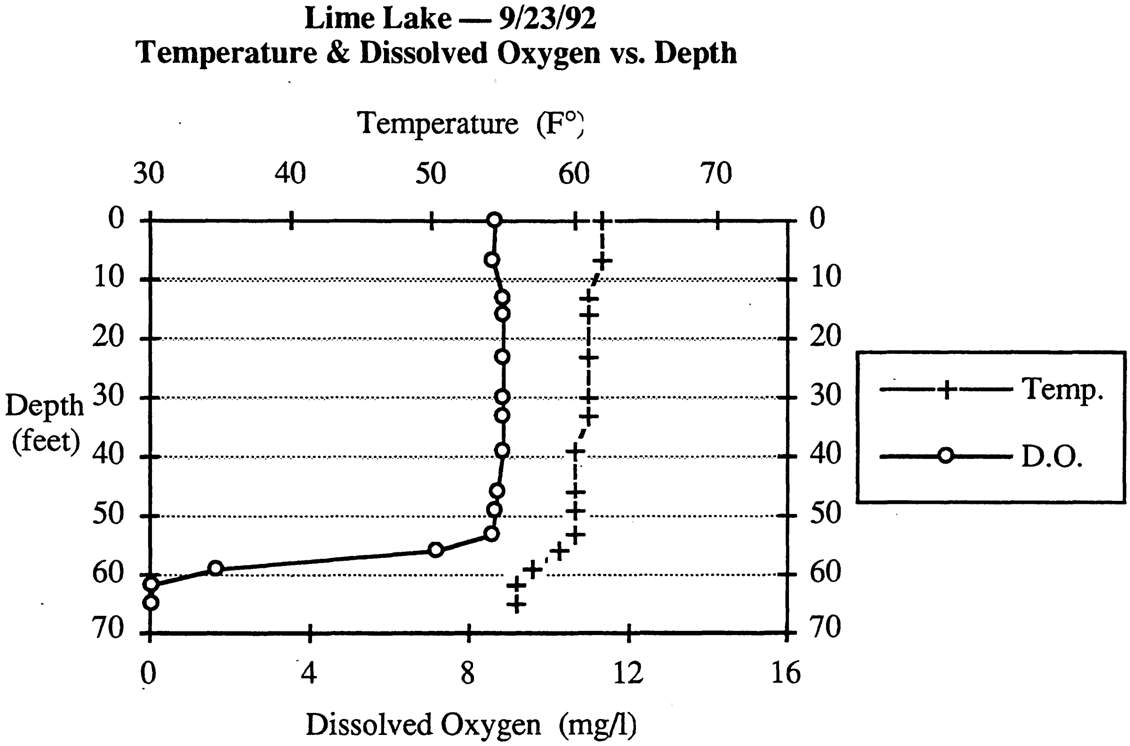


Figure 17b: Lime Lake temperature and dissolved oxygen measurements.

Little Traverse Lake 1991 data is in Figures 18a through 18i. They are similar to the Lime Lake graphs except that the DO levels drop earlier, the algal bloom is more defined, and the fall overturn occurred previous to September 24.

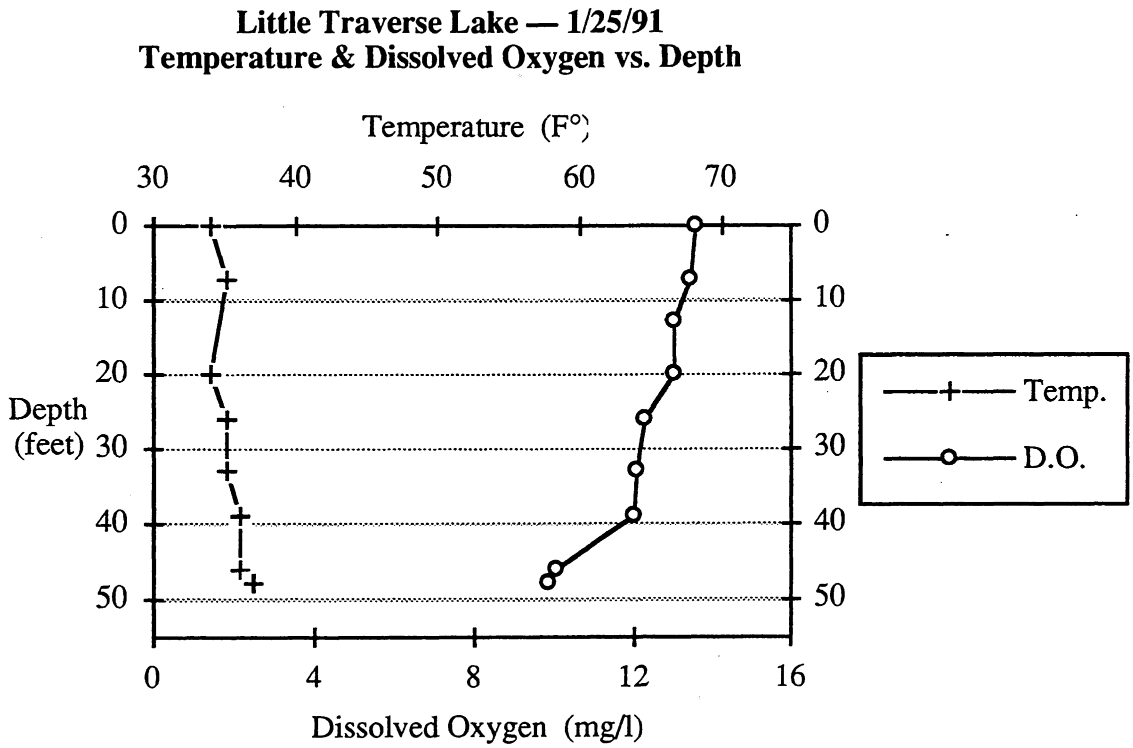


Figure 18a: Little Traverse Lake temperature and dissolved oxygen measurements.

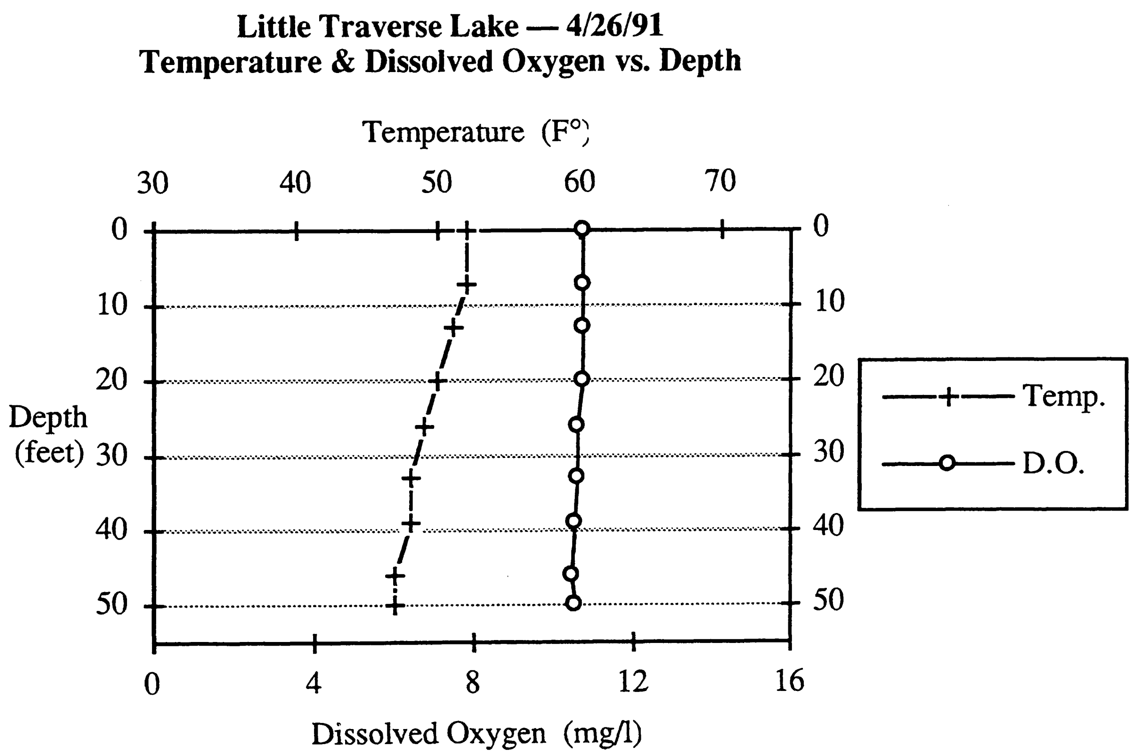


Figure 18b: Little Traverse Lake temperature and dissolved oxygen measurements.

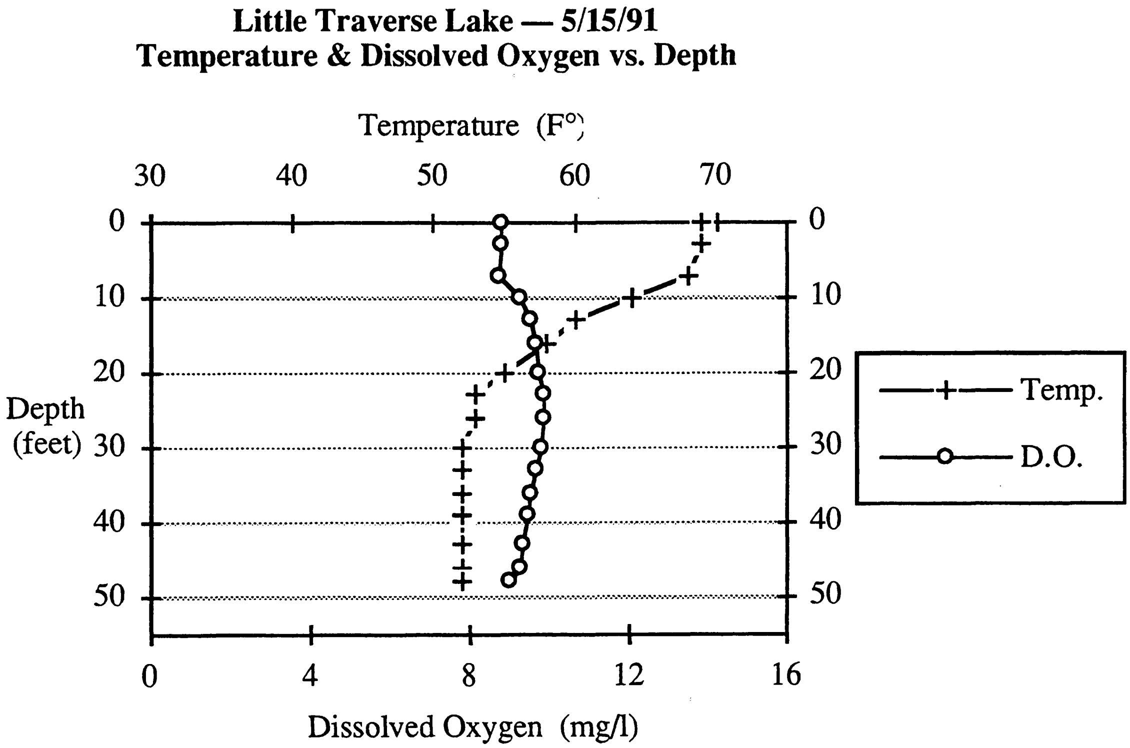


Figure 18c: Little Traverse Lake temperature and dissolved oxygen measurements.

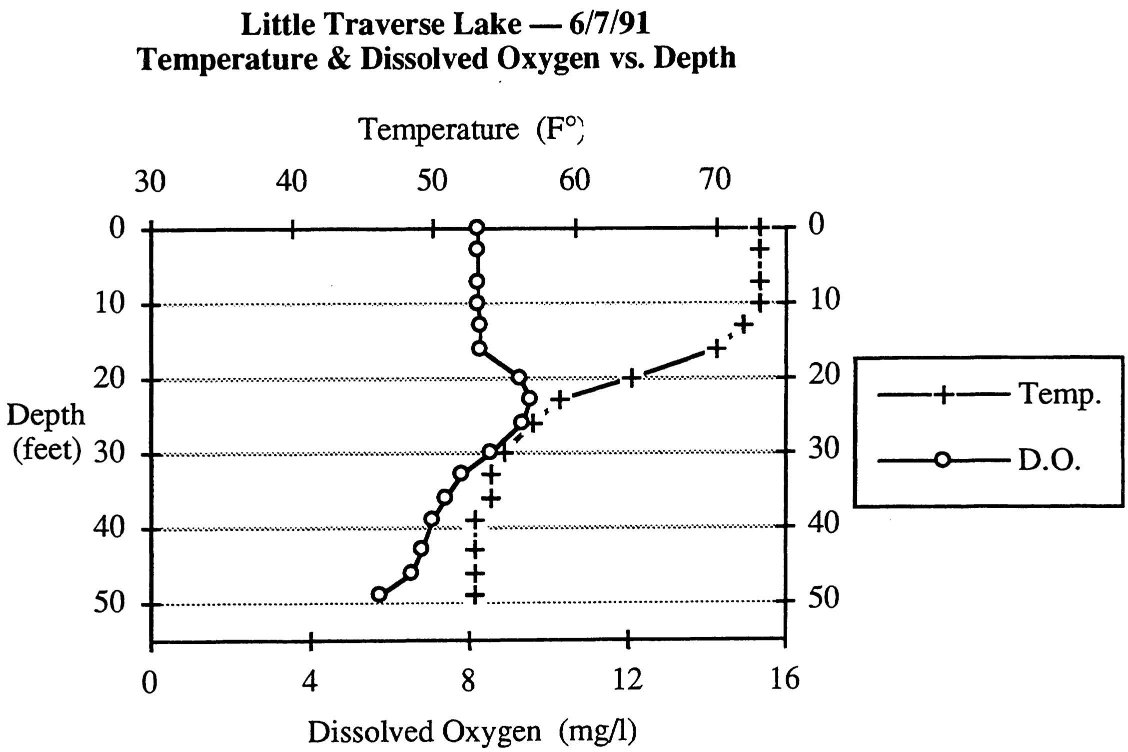


Figure 18d: Little Traverse Lake temperature and dissolved oxygen measurements.

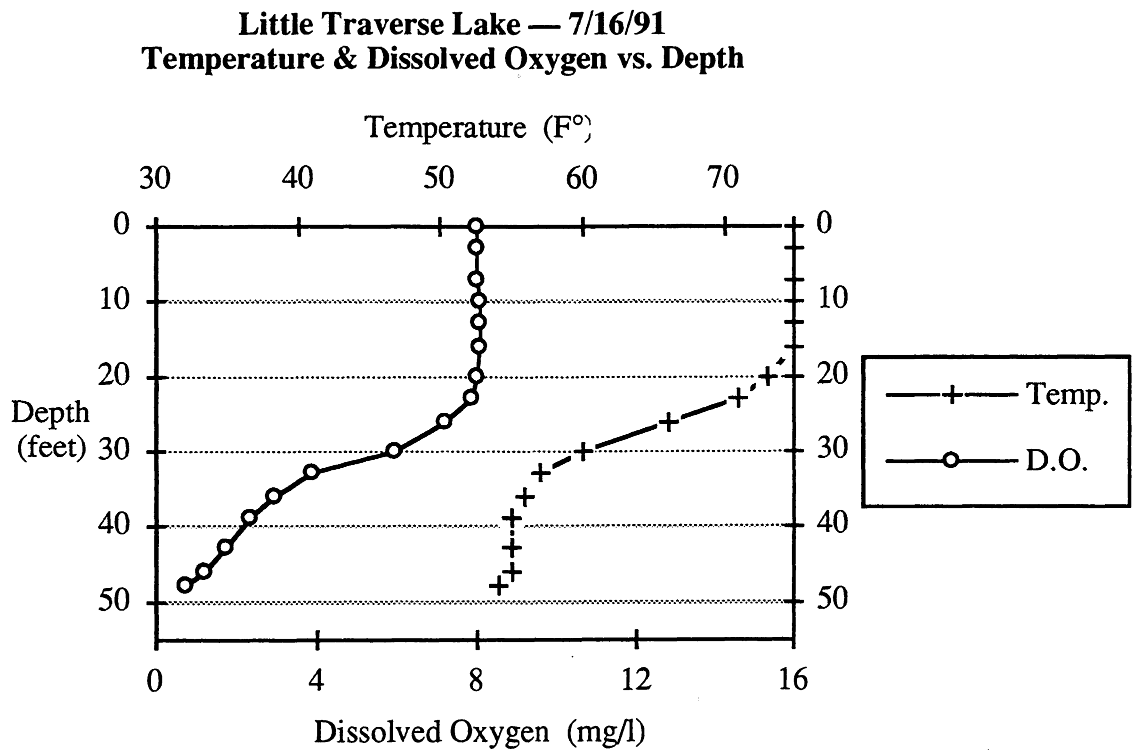


Figure 18e: Little Traverse Lake temperature and dissolved oxygen measurements.

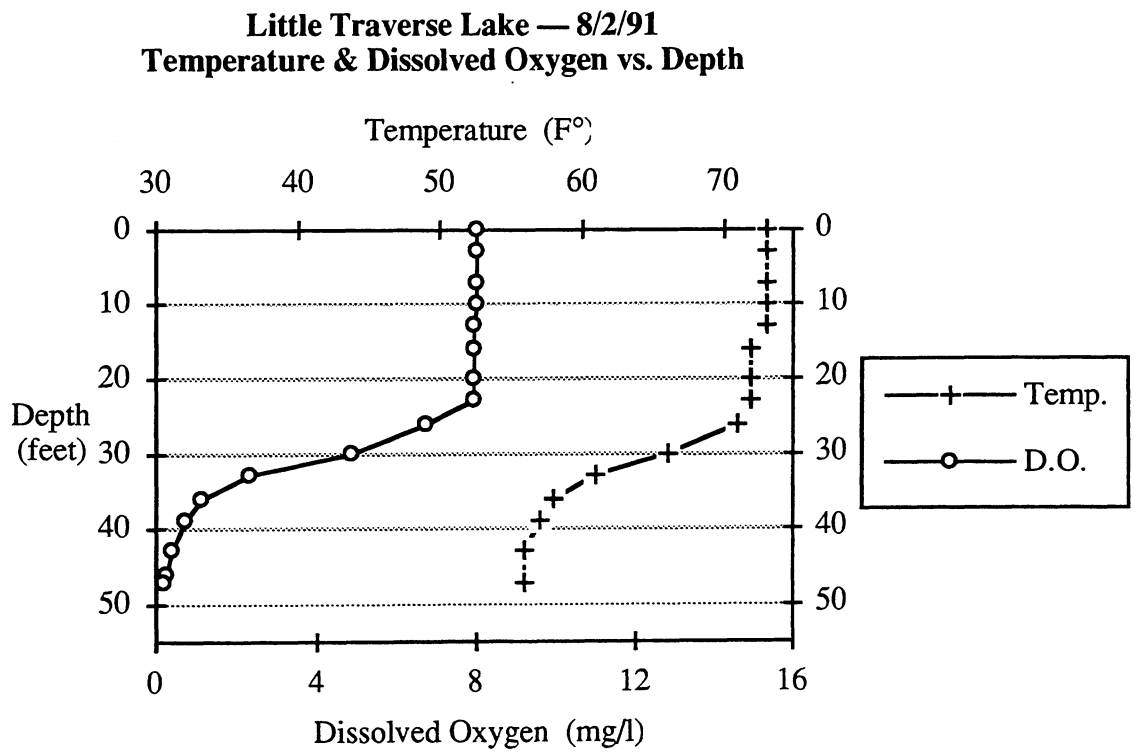


Figure 18f: Little Traverse Lake temperature and dissolved oxygen measurements.

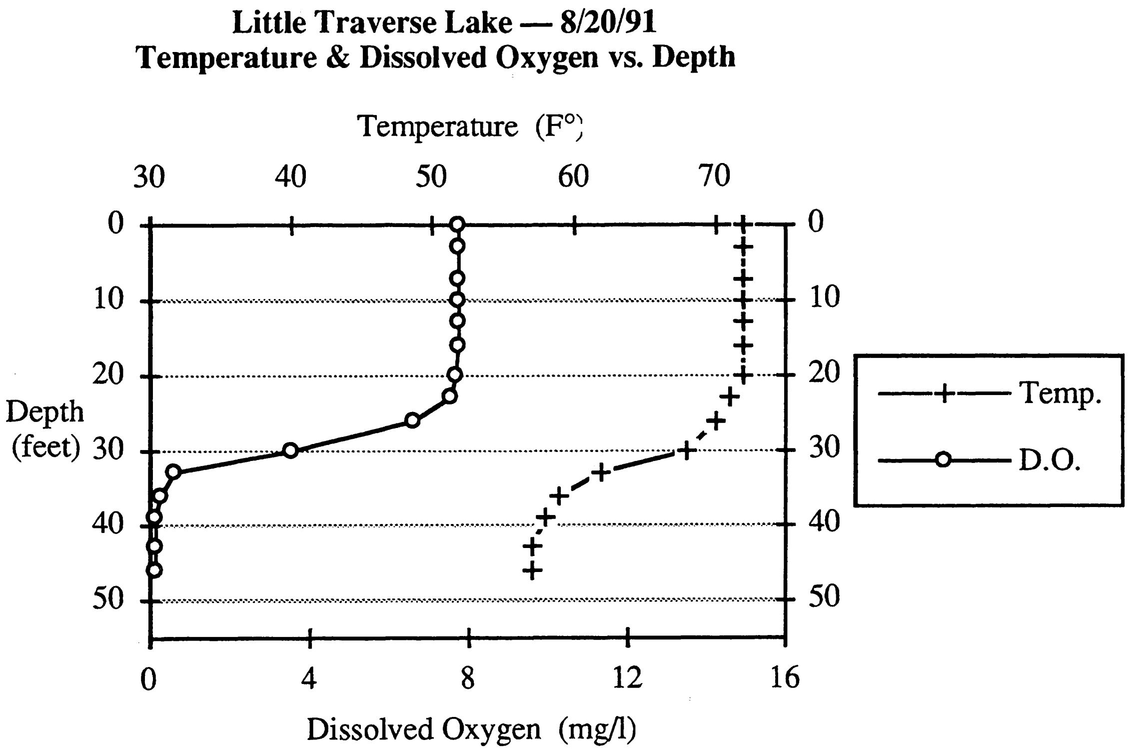


Figure 18g: Little Traverse Lake temperature and dissolved oxygen measurements.

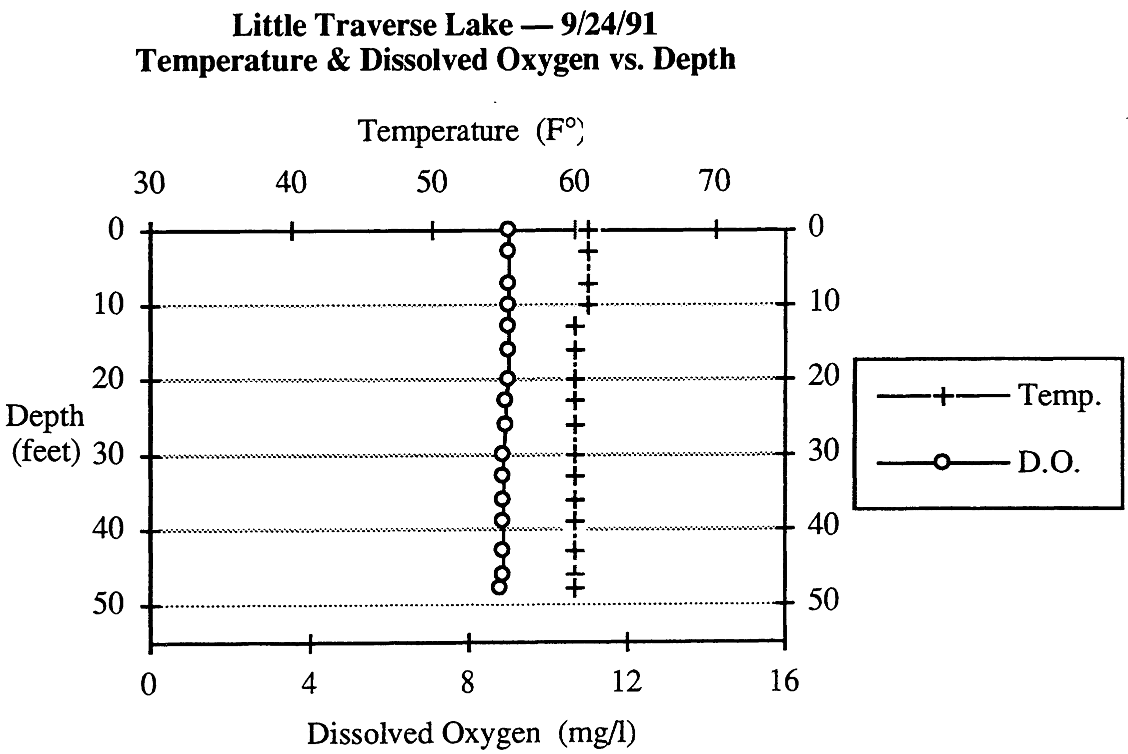


Figure 18h: Little Traverse Lake temperature and dissolved oxygen measurements.

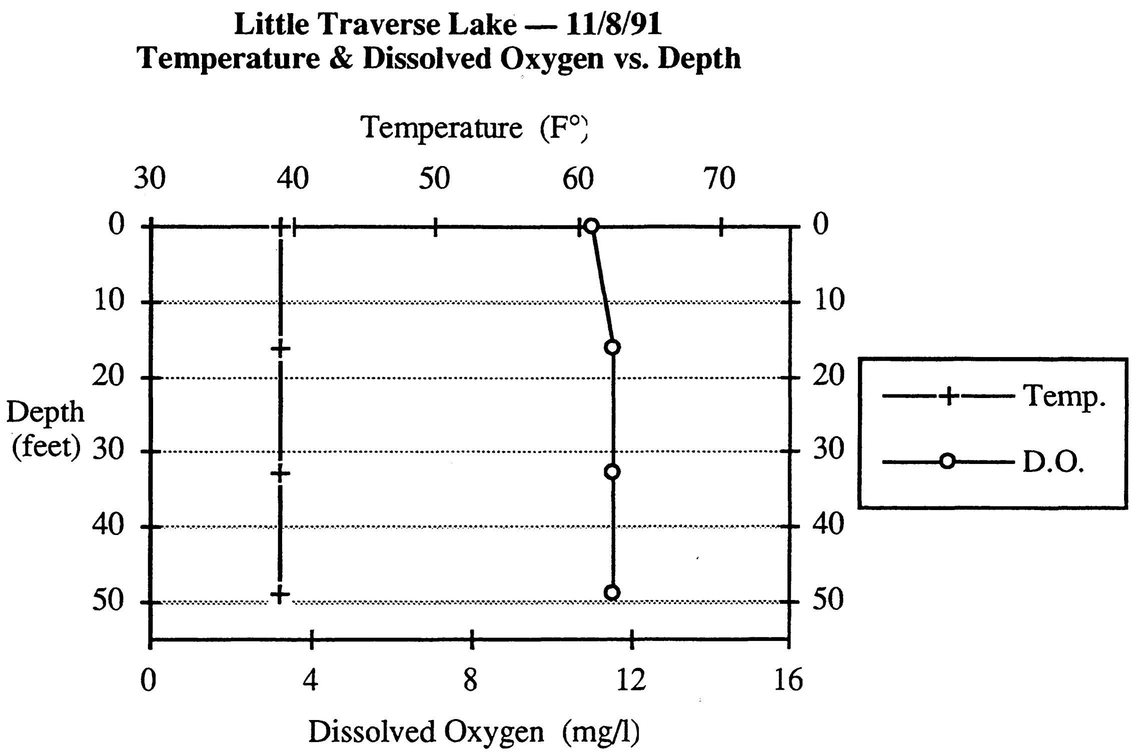


Figure 18i: Little Traverse Lake temperature and dissolved oxygen measurements.

The second type of comparisons of similar dates over multiple years attempt to determine whether there is a trend of declining lake quality. Earlier data from the Institute for Fisheries Research and the MDNR are graphed and compared with similar dates throughout the years. The problem with this comparison is insufficient data from previous years. It is unknown if the data from these early years is from a "normal" year, or if something had occurred that year which would skew the data.

The data would indicate that there has been a trend of decreasing DO throughout the years. There is good data for both Lime and Little Traverse Lakes in early August and late August. The data was not combined since there is a significant difference between early and late in the month.

Comparisons of Lime Lake on August 7, 1947, August 6, 1973, August 2, 1991, and August 6, 1992, are in Figures 19a through 19d.

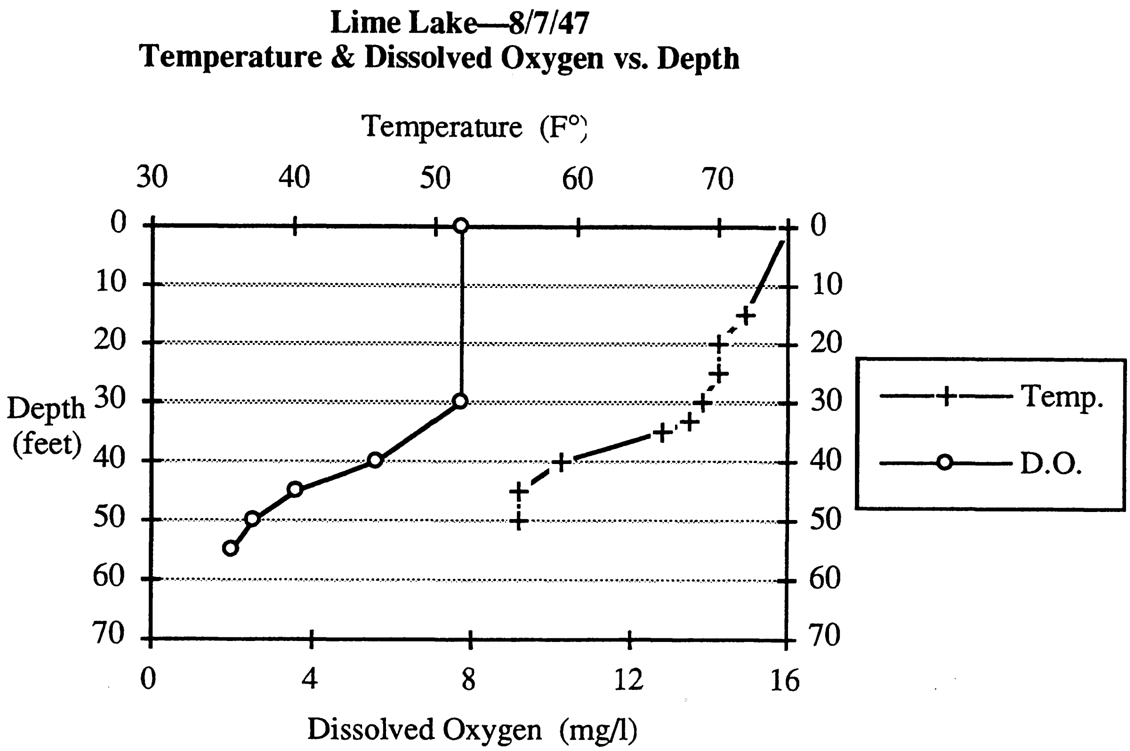


Figure 19a: Lime Lake temperature and dissolved oxygen measurements.

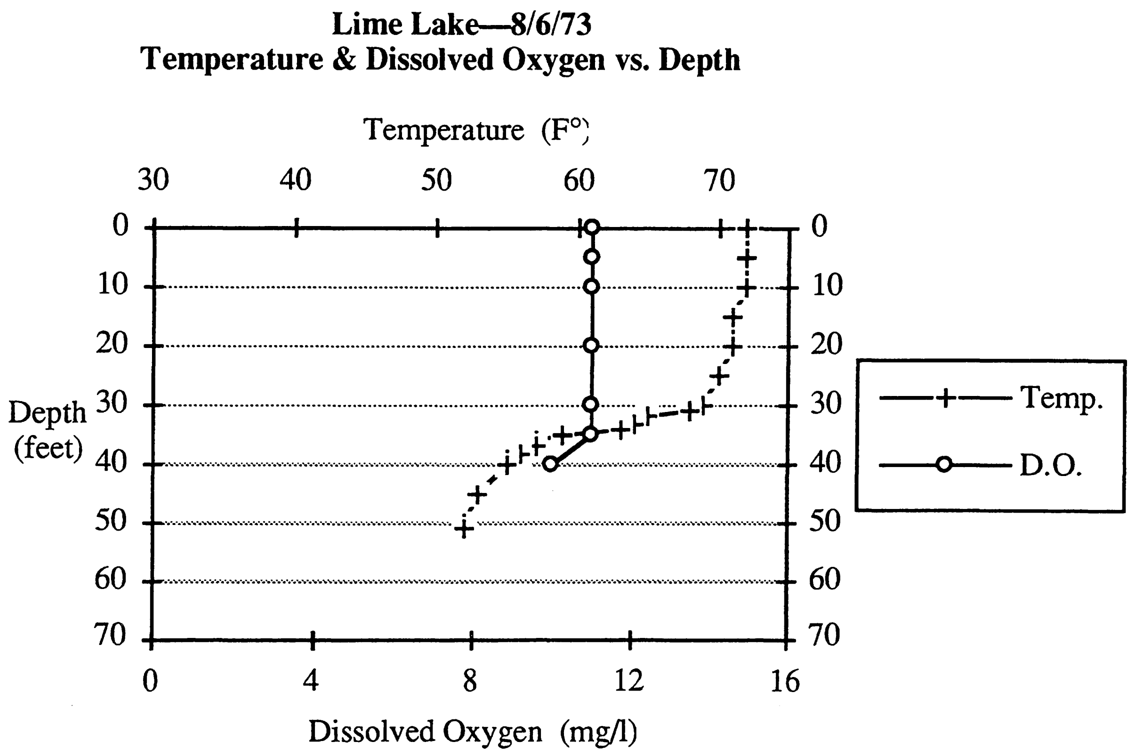


Figure 19b: Lime Lake temperature and dissolved oxygen measurements.

Lime Lake — 8/2/91
Temperature & Dissolved Oxygen vs. Depth

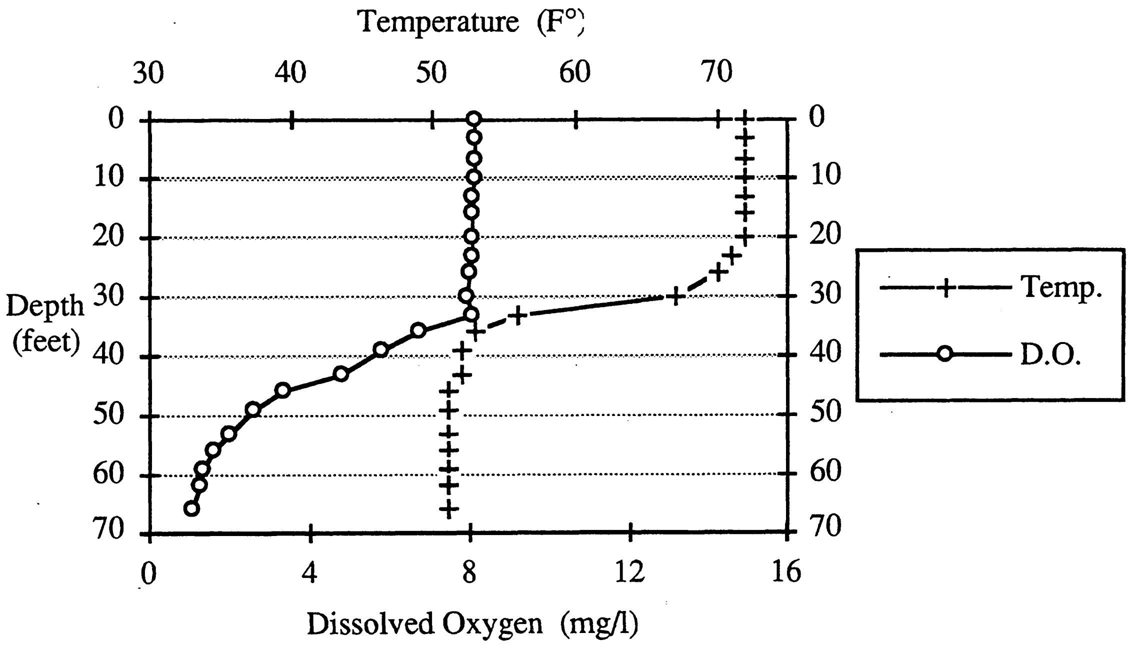


Figure 19c: Lime Lake temperature and dissolved oxygen measurements.

Lime Lake — 8/6/92
Temperature & Dissolved Oxygen vs. Depth

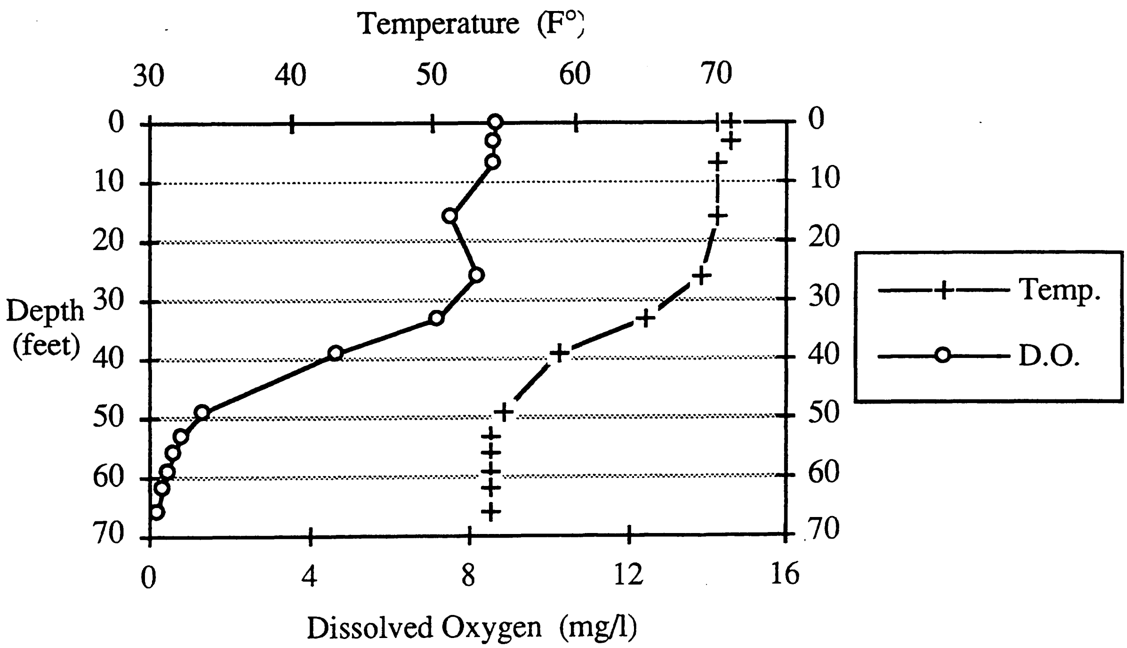


Figure 19d: Lime Lake temperature and dissolved oxygen measurements.

The 1990 data were not included because the closest test date was seven days previous to the other dates being investigated. The temperatures are similar in all the years. The DO measurements are similar in all years except 1973 when there is a significantly higher level than the other years. Because forty feet is the deepest measurement it is unknown if the hypolimnion results are comparable to the other years. The unusually high DO levels in the first forty feet in 1973 may be explained by an unusual mixing of the epilimnion and hypolimnion for that year. It may be concluded from these results that there was no degradation of the lakes over these years.

Comparison for Little Traverse Lake in early August is limited by sparse historical data over the years. August 1, 1978, July 27, 1990, August 2 1991, and July 24, 1992, are shown in Figures 20a through 20d. The 1978 DO concentrations are higher than the following years. In 1978 there is still approximately 2 mg/l of DO at a depth of forty-five feet, whereas in other years the DO levels are near depletion at depths of thirty five feet. This might indicate that the situation was better in 1978 than it is now, but this cannot be conclusive.

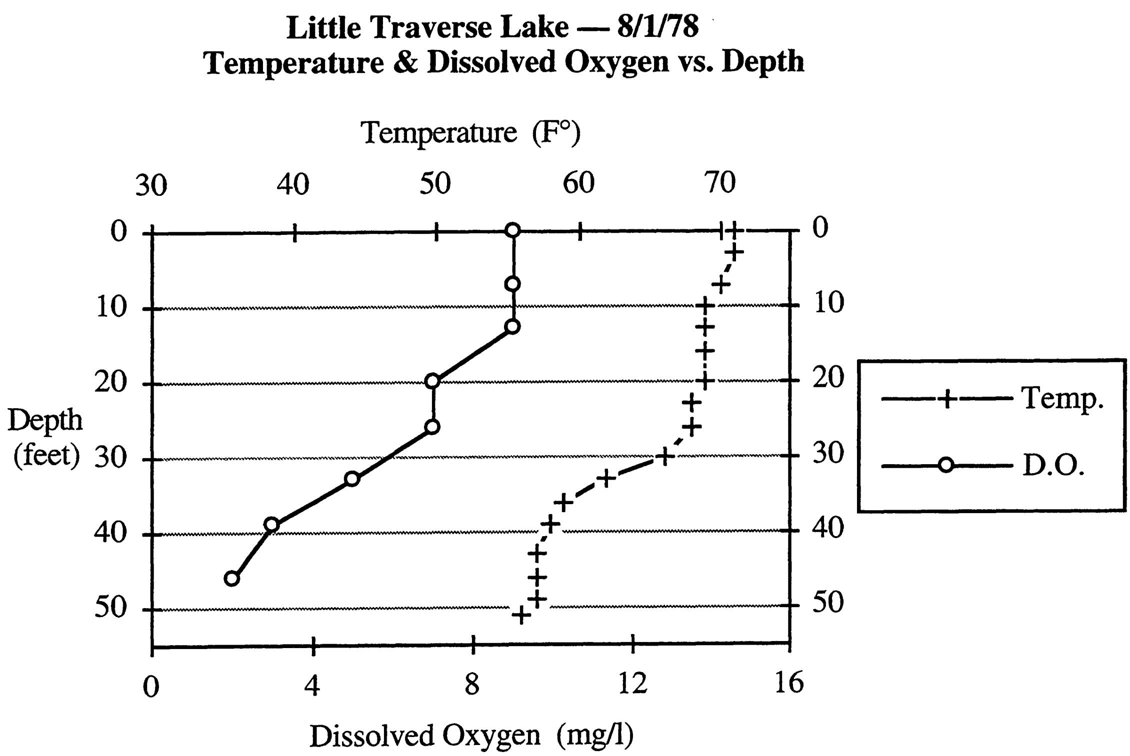


Figure 20a: Little Traverse Lake temperature and dissolved oxygen measurements.

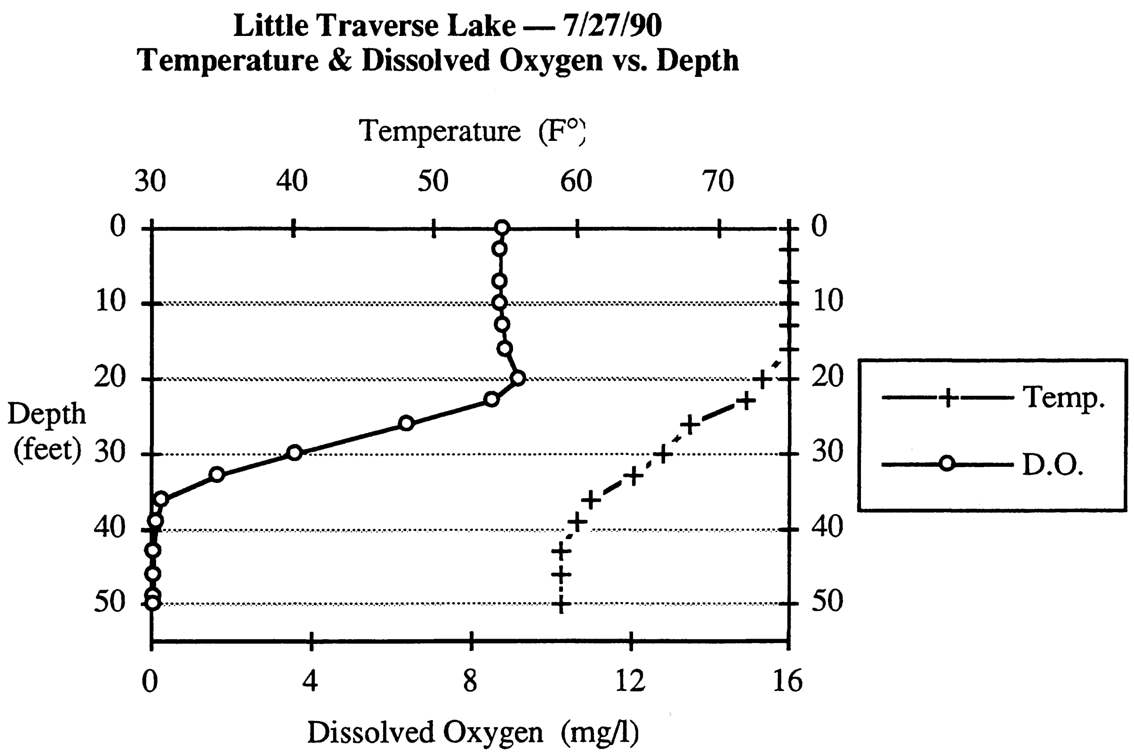


Figure 20b: Little Traverse Lake temperature and dissolved oxygen measurements.

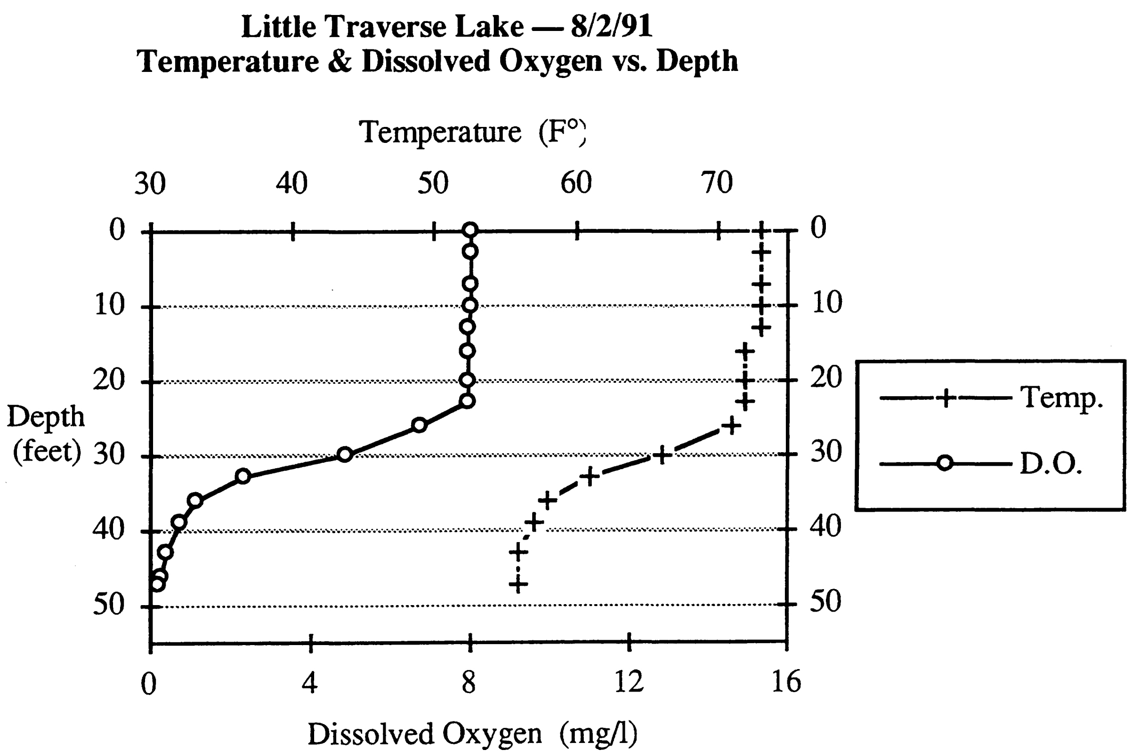


Figure 20c: Little Traverse Lake temperature and dissolved oxygen measurements.

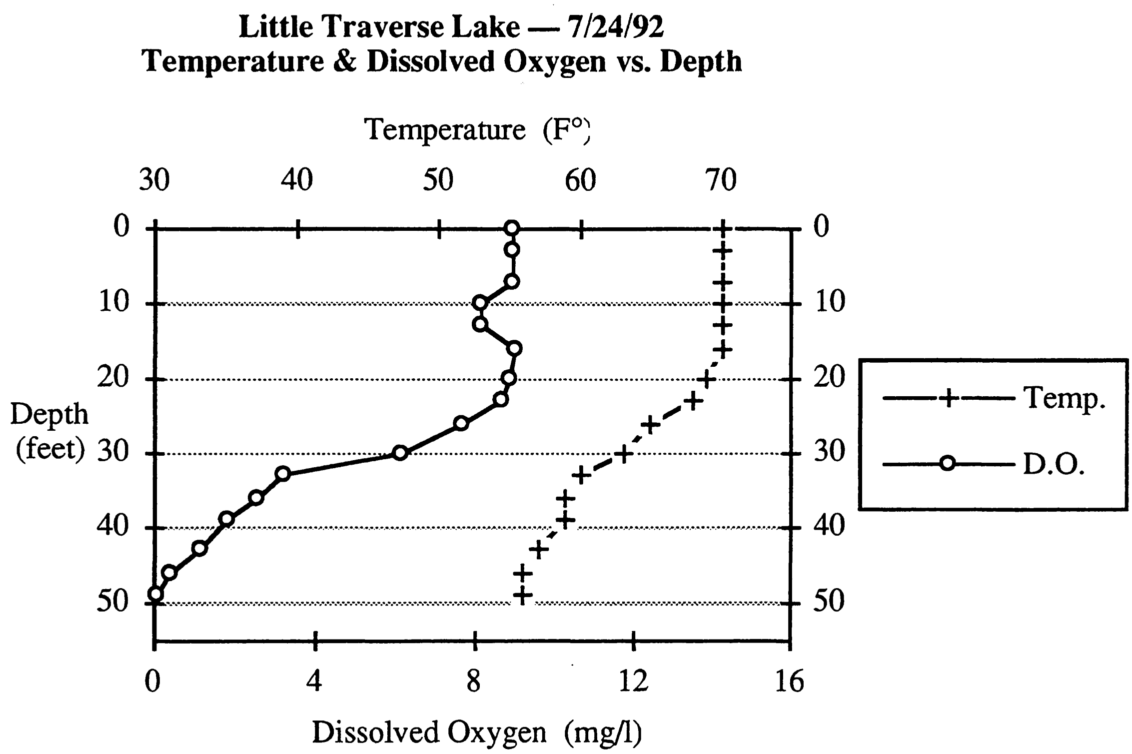


Figure 20d: Little Traverse Lake temperature and dissolved oxygen measurements.

The late August data is slightly better over the years with five dates in Lime Lake to compare instead of four. This Lime Lake data is compared for August 30, 1949, August 26, 1980, August 20,1990, August 20, 1991, and August 25, 1992 in Figures 21a through 21e. There is fluctuation in the temperature data between the years, with 1949 having the highest temperature in the hypolimnion, but also the highest concentrations of DO. The DO concentrations are only slightly worse in 1980, and are similar to 1991. In both 1990 and 1992 the DO situation became severe. Conditions were near anoxia at depths of fifty feet and lower. From the limited information provided, a trend might be assumed that Lime Lake is becoming worse over time.

Lime Lake—8/30/49
Temperature & Dissolved Oxygen vs. Depth

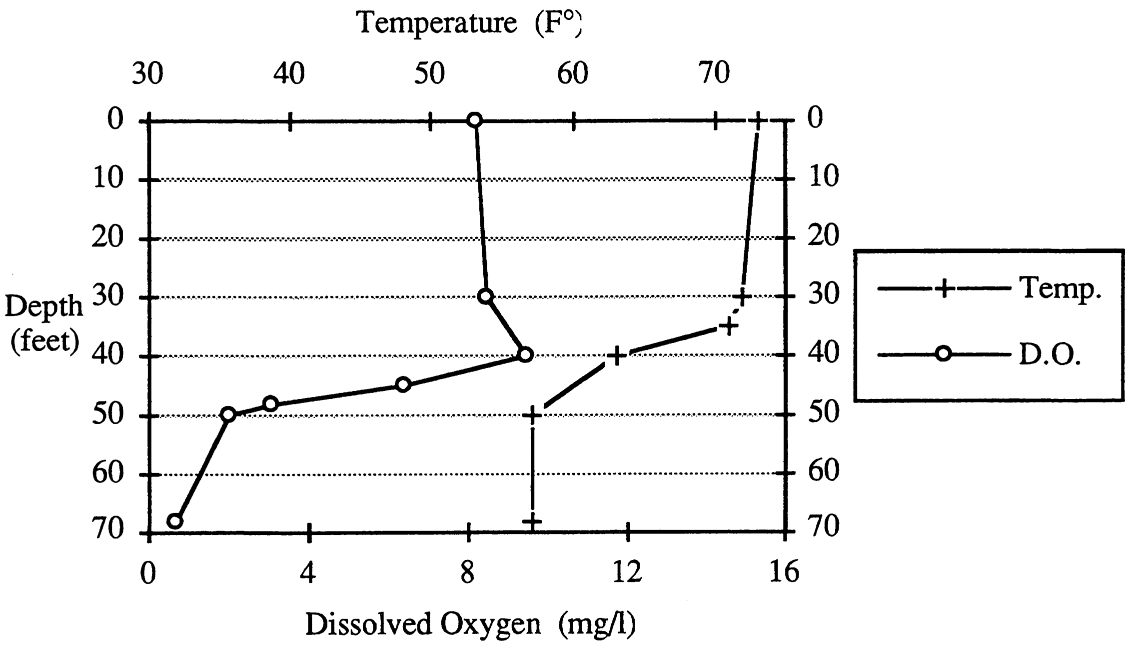


Figure 21a: Lime Lake temperature and dissolved oxygen measurements.

Lime Lake—8/26/80
Temperature & Dissolved Oxygen vs. Depth

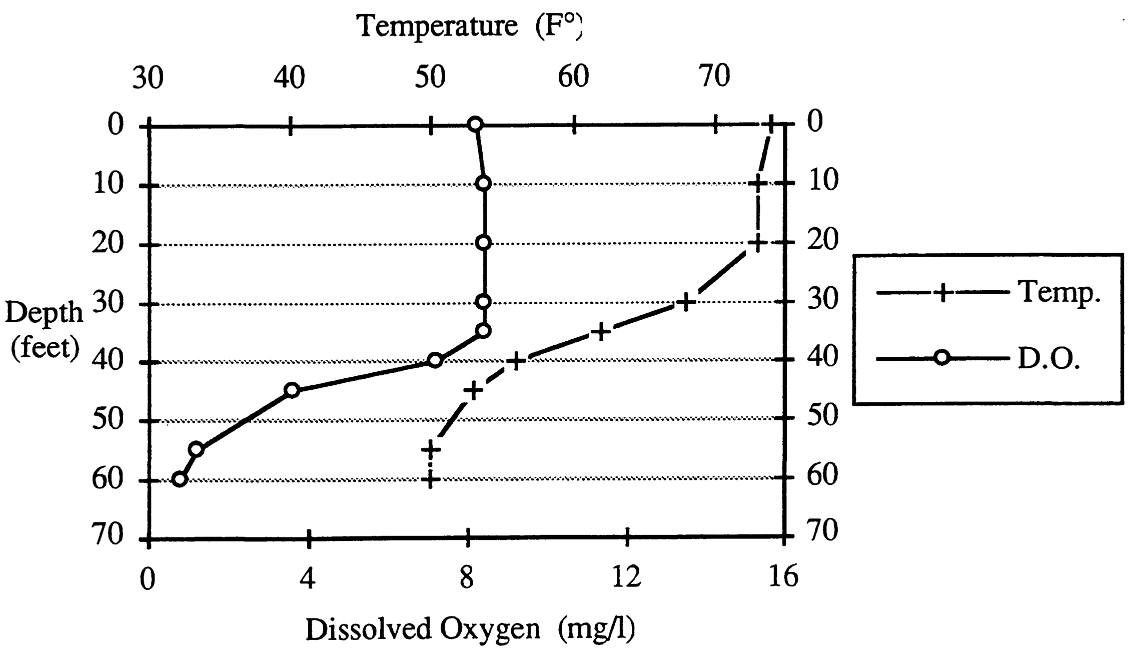


Figure 21b: Lime Lake temperature and dissolved oxygen measurements.

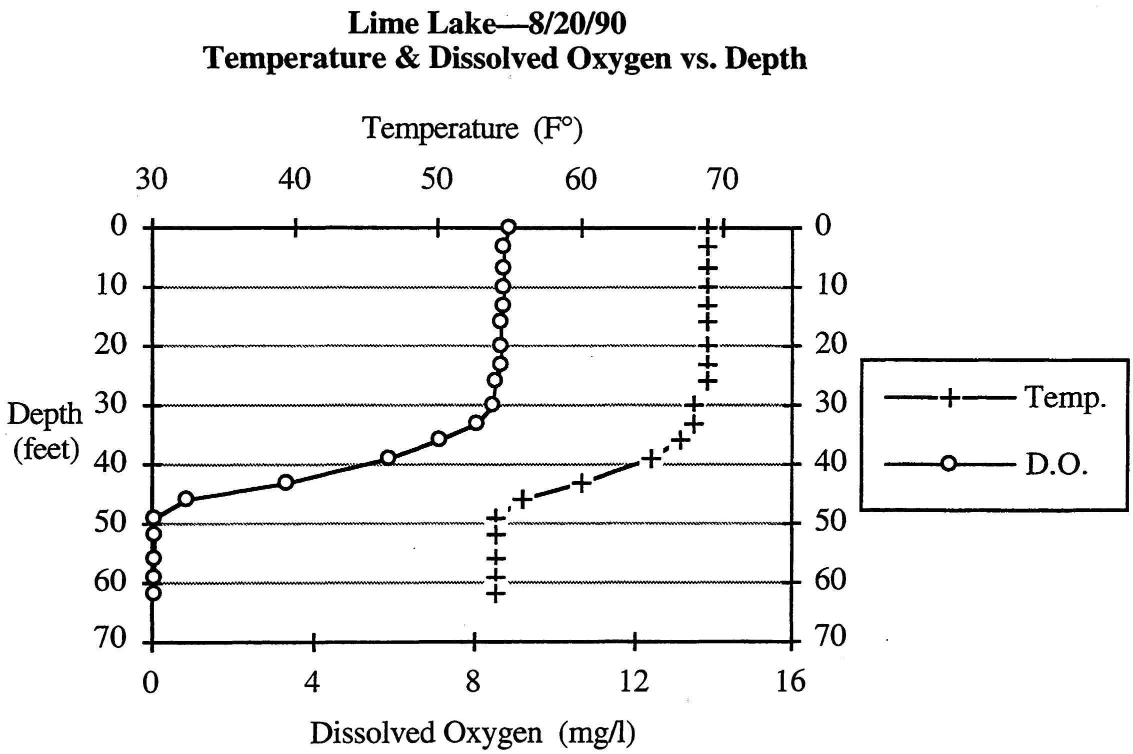


Figure 21c: Lime Lake temperature and dissolved oxygen measurements.

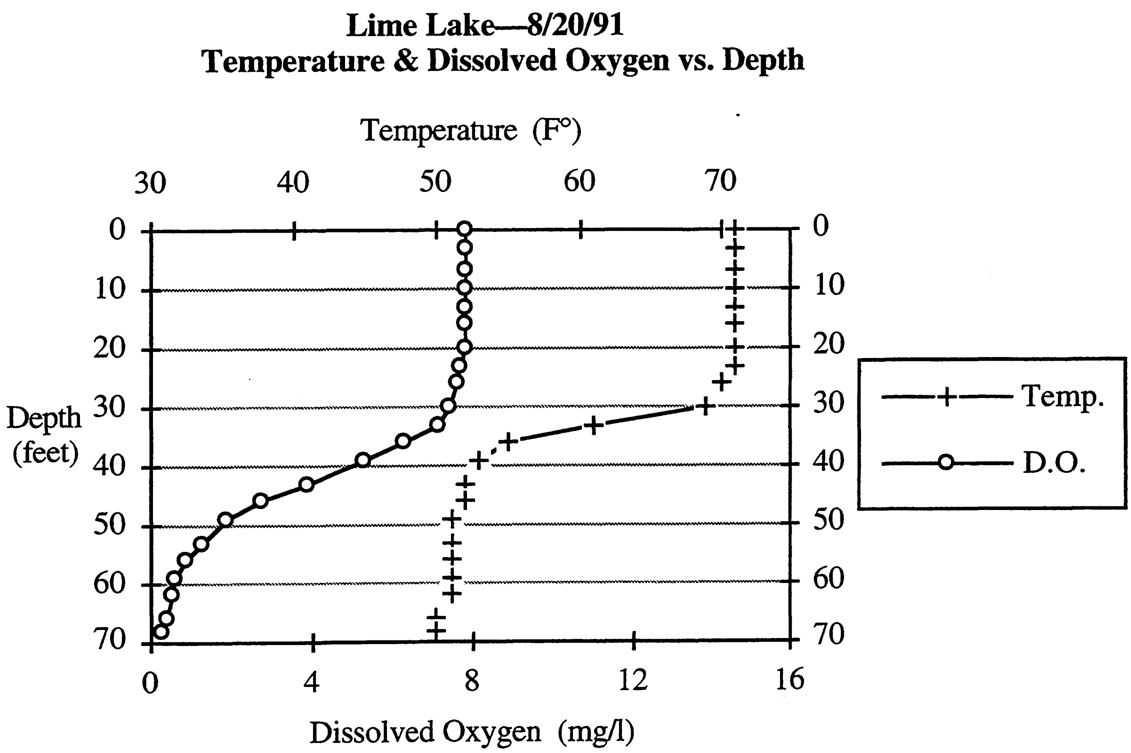


Figure 21d: Lime Lake temperature and dissolved oxygen measurements.

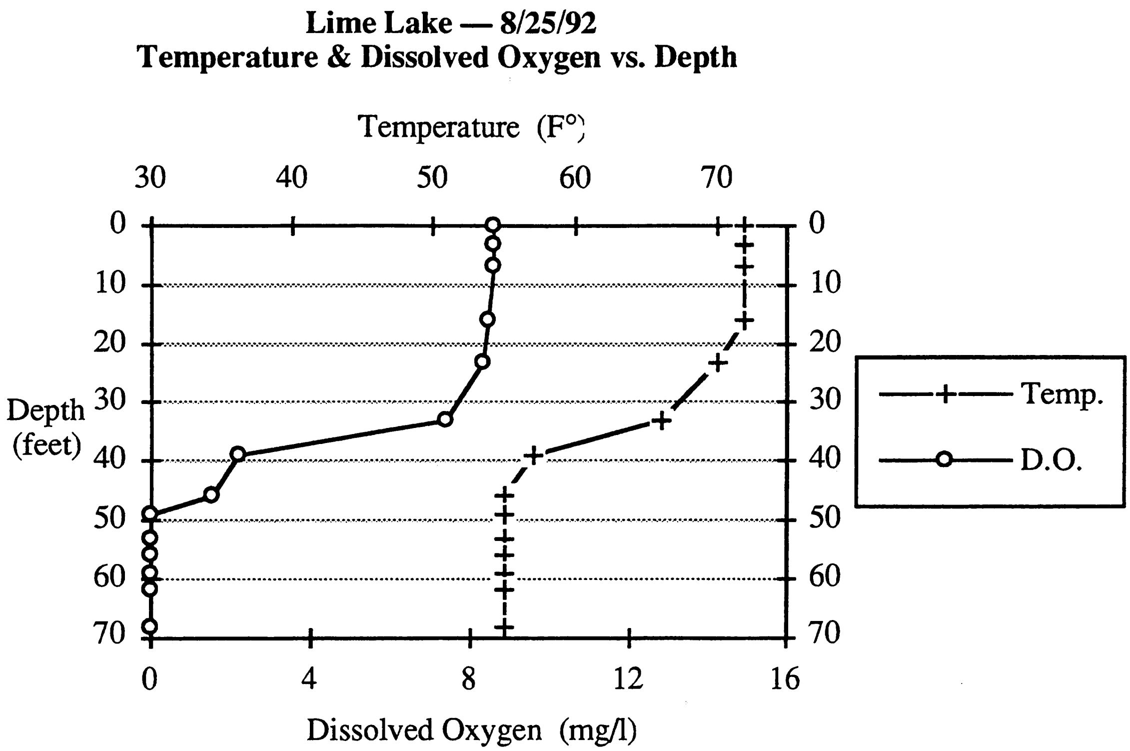


Figure 21e: Lime Lake temperature and dissolved oxygen measurements.

Little Traverse Lake data for August 30, 1949, August 20, 1990, August 20, 1991, and August 25, 1992 are compared in Figures 22a through 22d. There is a significantly higher amount of DO in the hypolimnion in 1949 than there is in the 1990's, although depleted near fifty feet in 1949. This would suggest that the conditions may have become worse in recent years where DO levels have nearly disappeared at forty feet.

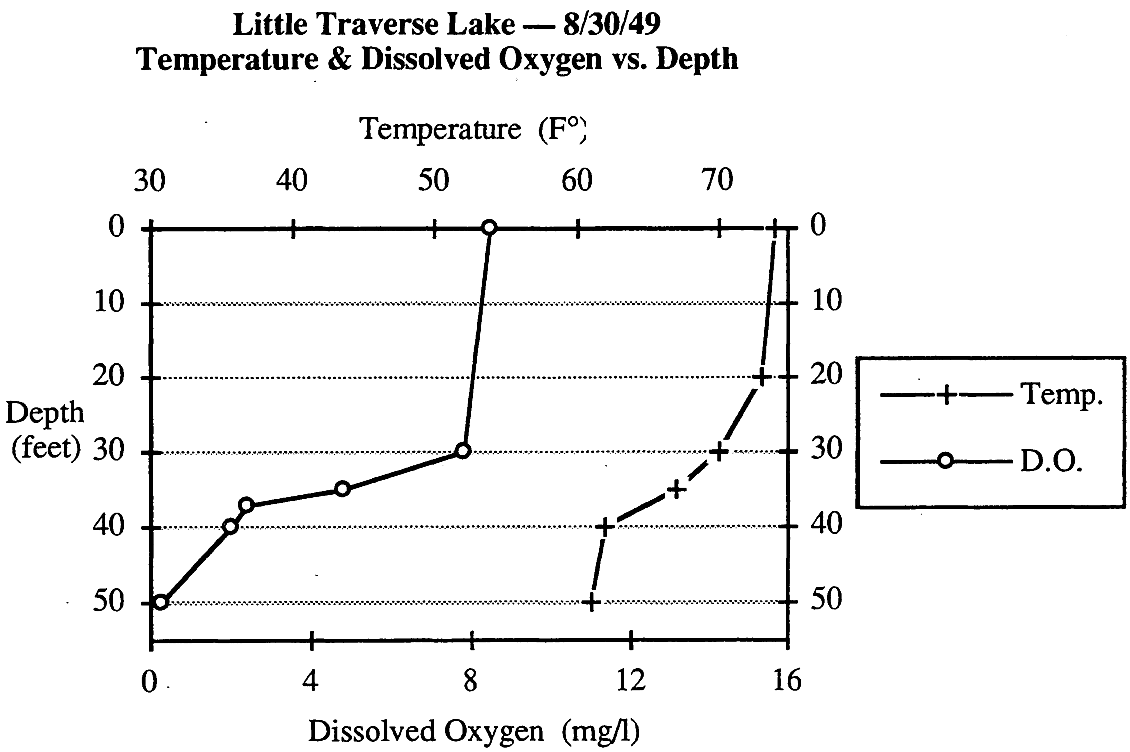


Figure 22a: Little Traverse Lake temperature and dissolved oxygen measurements.

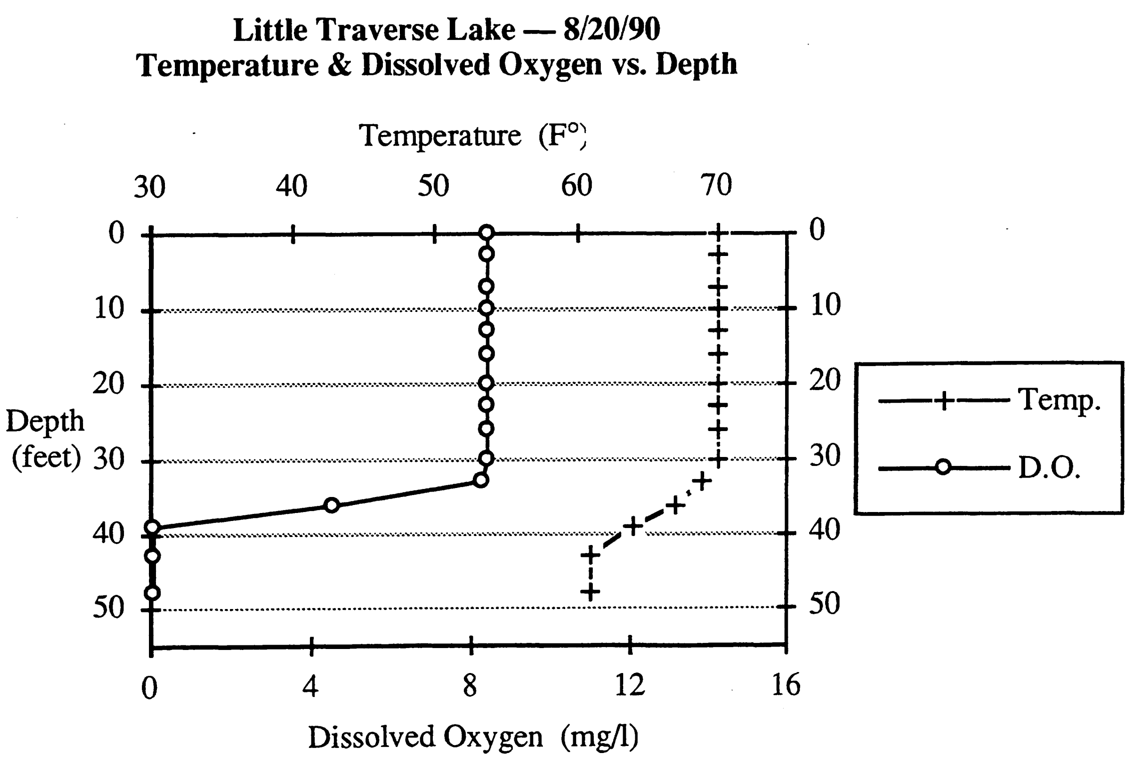


Figure 22b: Little Traverse Lake temperature and dissolved oxygen measurements.

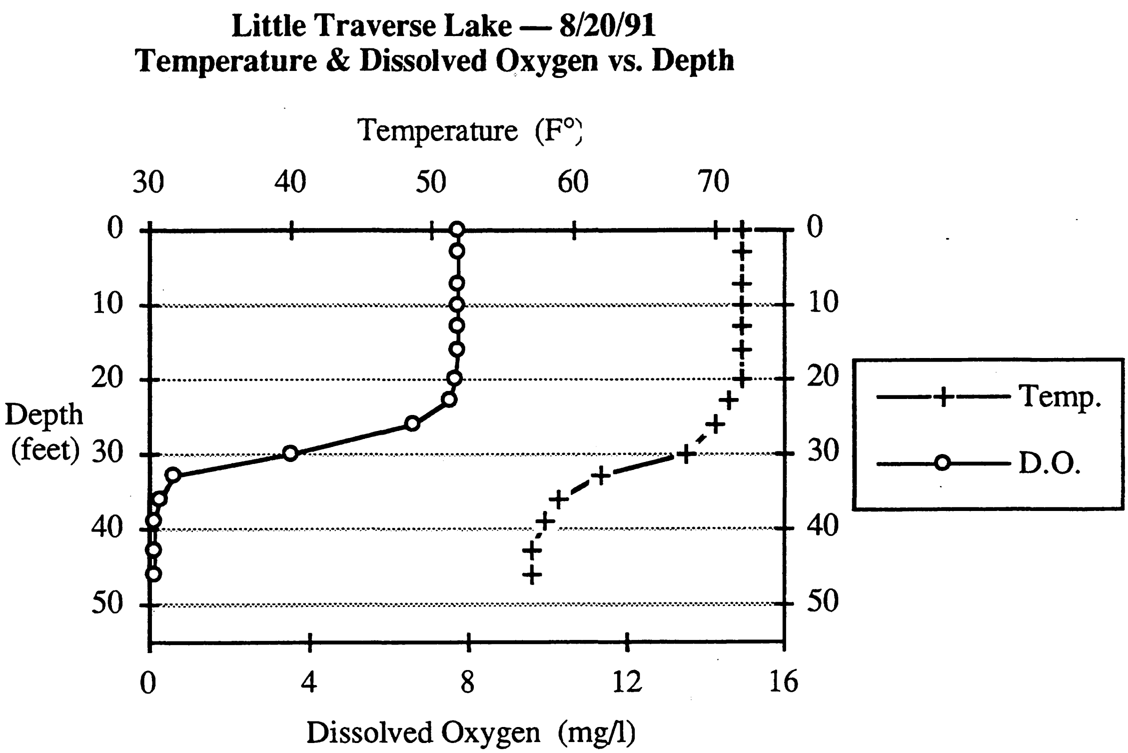


Figure 22c: Little Traverse Lake temperature and dissolved oxygen measurements.

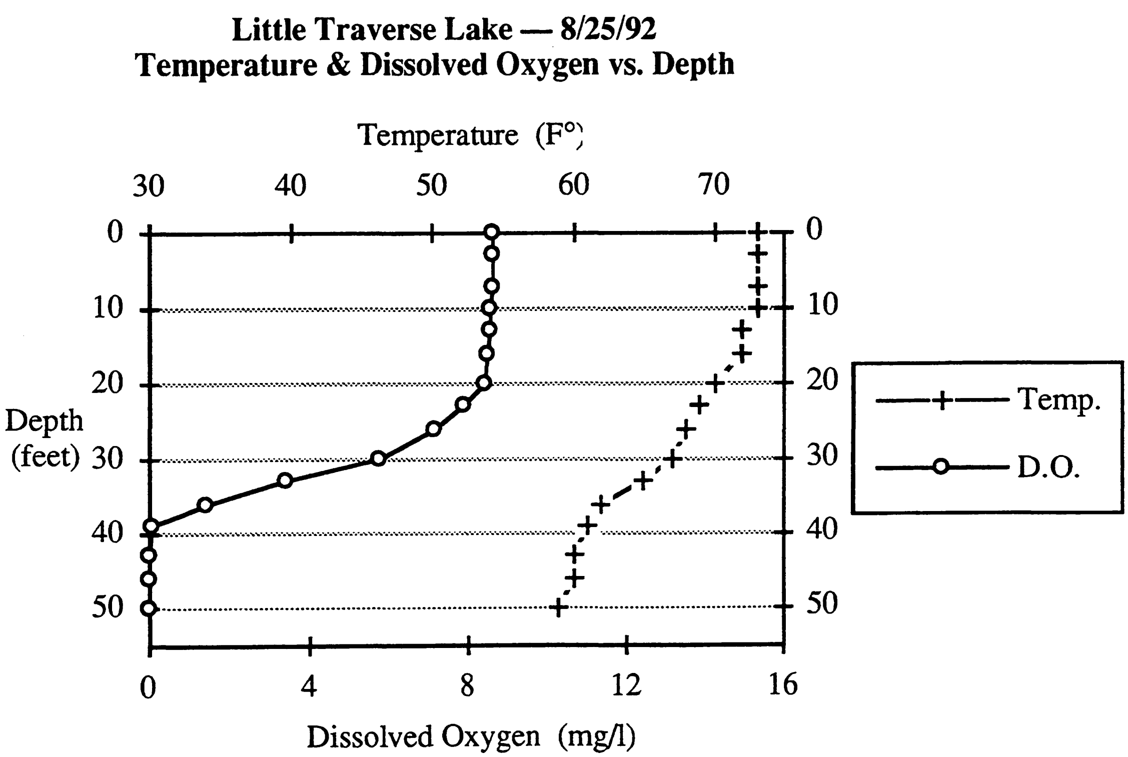


Figure 22d: Little Traverse Lake temperature and dissolved oxygen measurements.

In every case these comparisons indicate either no significant change or worsening conditions for the DO concentrations in the hypolimnion. Close monitoring should take place to identify a possible worsening trend. Testing over the years should target specific dates, times of day, and weather conditions to give the most accurate comparisons. Optimal dates would be just previous to ice melting, just after ice melting, in late August when there are other historical dates to compare, and after fall overturn. Other tests in the spring and summer are helpful to monitor the stratification process and the occurrence of algal blooms.

Another factor affecting water temperatures in Lime and Little Traverse Lakes, especially around the perimeter edges, is input of ground water which is significantly colder than land surface. Cold water can potentially carry more dissolved oxygen than warmer water, but groundwater contains large amounts of carbon dioxide and little oxygen, so lake DO does not increase.

According to Wetzel [69], the DO levels for a normal oligotrophic lake should be similar throughout the water column during summer stagnation. Possible reasons why these lakes may be running out of DO include: 1) Large amounts of ammonia (NH_4), organic nitrogen, and nitrite (NO_2) are being oxidized into Nitrate (NO_3) [70]; 2) Large amounts of organic matter entering from outside sources, such as streams carrying large amounts of nitrogen in various forms, since there seems not to be an abundance of aquatic organisms in either lake; 3) Due to the shape of the basin and the shallowness of the lakes, there is much more epilimnion than there is a hypolimnion, hence, dead organic matter accumulates on the hypolimnion bottom in greater concentration than would be expected in a lake with steep banks; and 4) large amounts of anoxic groundwater seeping into the basin.[70]

b. Secchi Disc

This test is probably the one most often taken on both lakes. There are two easy ways to use the results. The first is to see how deep the disc can be read in the water, and the second is to convert this reading to a Trophic State Index (TSI) number (See heading below: Trophic State Index from Secchi, Phosphorus, Chlorophyll *a* for results).

Figure 23 of Lime Lake, shows that during each of the years 1990, 1991, and 1992, the least light penetration is in June, when most algal blooms occur. Comparing data from multiple years on similar dates in Figure 24 it can be seen on August 30, 1949, August 26, 1980, August 20, 1990, August 20, 1991, and August 25, 1992 that the light penetration was much further in the two earlier dates than it is in the recent years. Although the data is sparse, there does appear to be a trend of declining water quality.

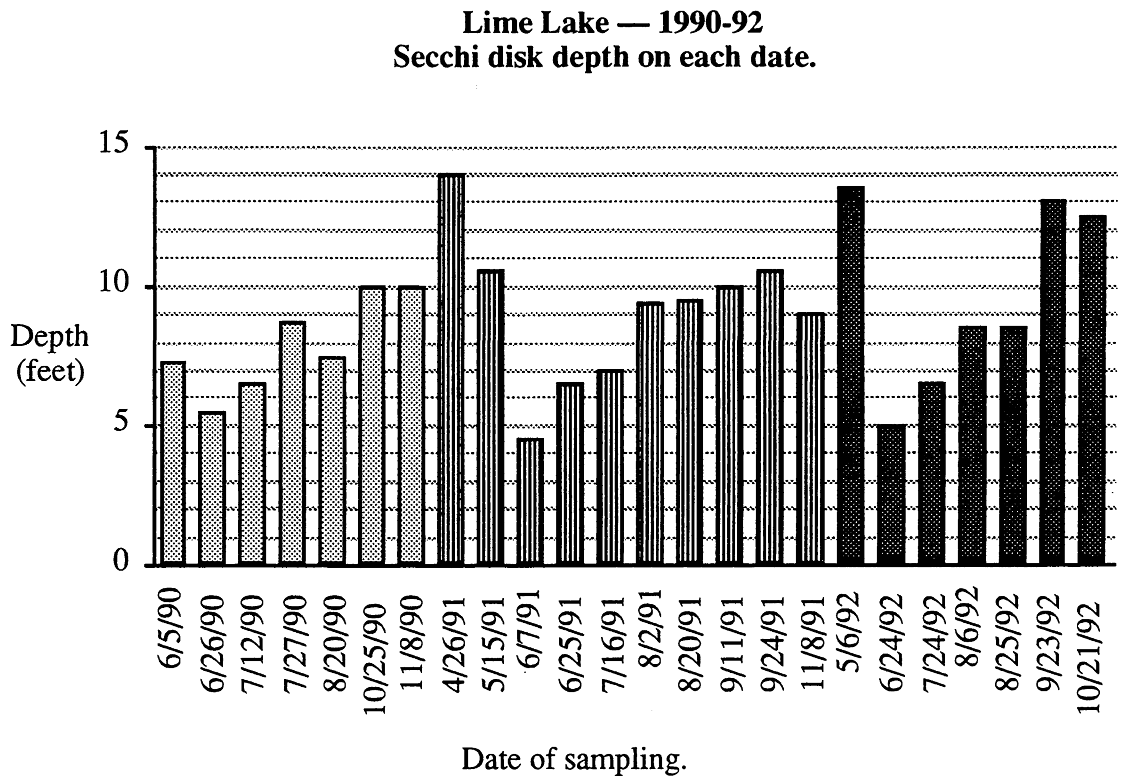


Figure 23: Lime Lake Secchi Disc Depth.

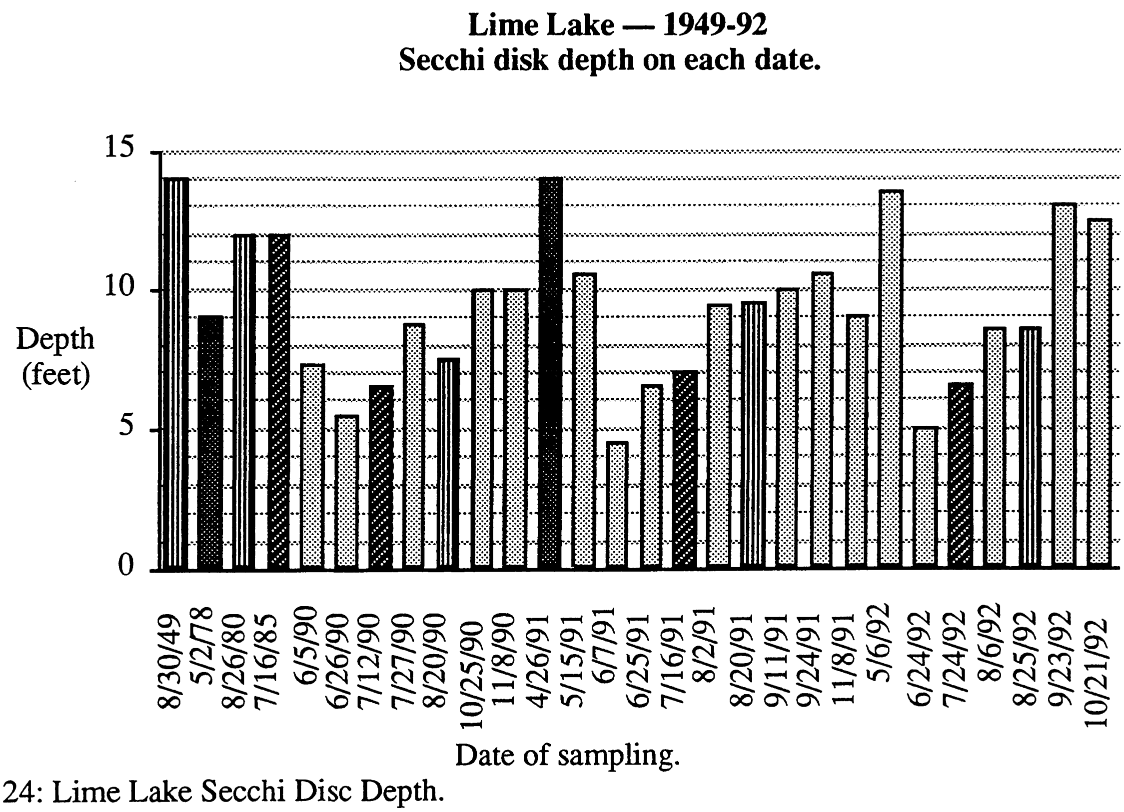


Figure 24: Lime Lake Secchi Disc Depth.

Figure 25 of Little Traverse Lake shows that in 1990, the least visibility occurred in late June to mid July. In 1991 the results were more erratic, with visibility being somewhat less during the summer. In 1992, there is a more even gradation from high visibility in March, gradually declining until early August. Historic data in Figure 26 for this lake shows that in late August, the visibility was slightly better in 1949. When comparing the early August data, the visibility was somewhat worse in 1978. This information is inconclusive due to the lack of data.

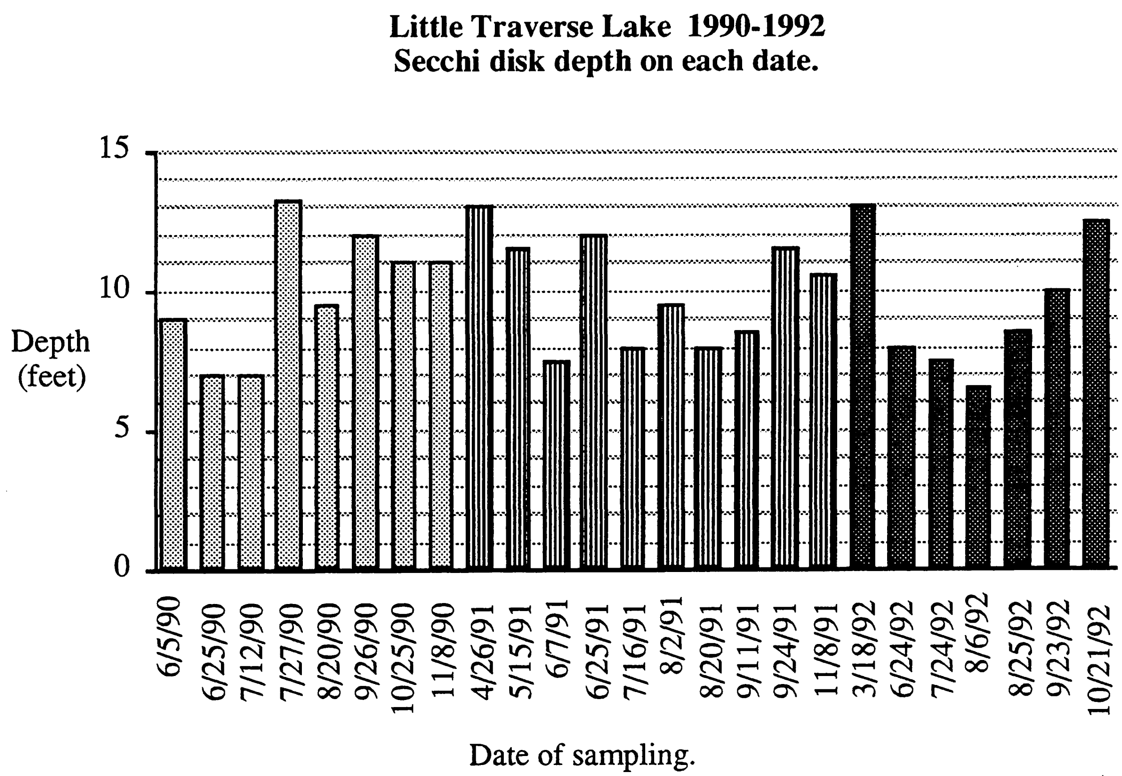


Figure 25: Little Traverse Lake Secchi Disc Depth.

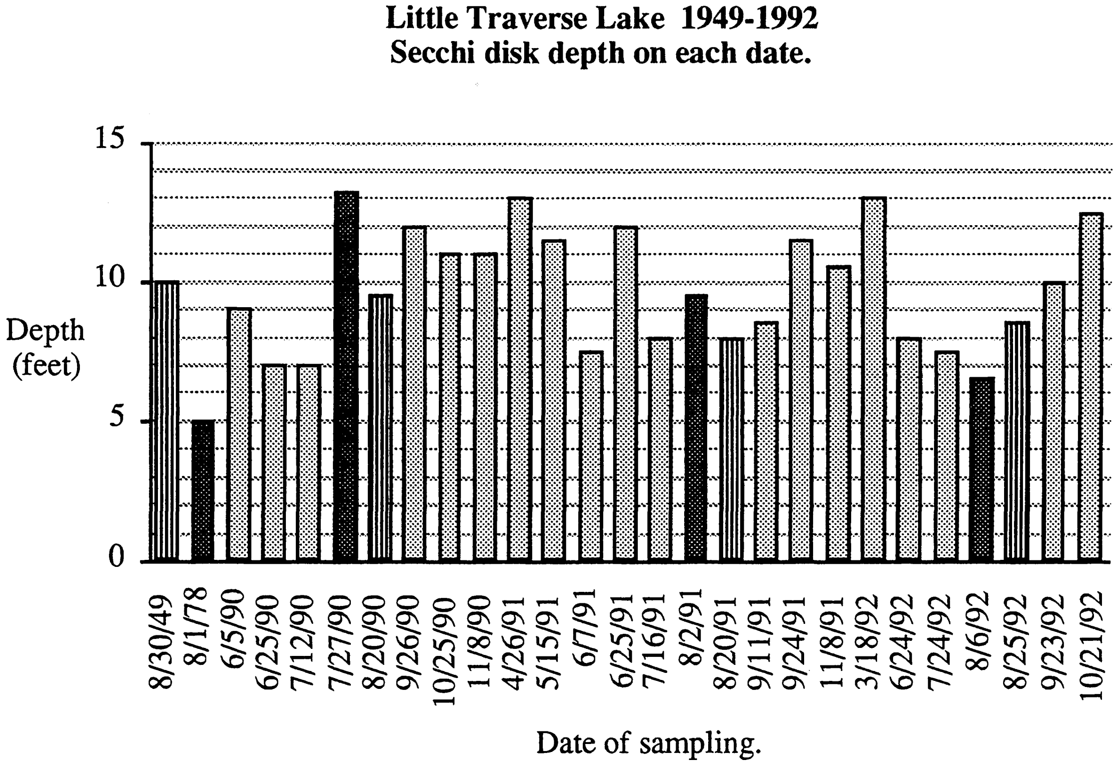


Figure 26: Little Traverse Lake Secchi Disc Depth.

c. Phosphorus

In most cases phosphorus is the element limiting the biological productivity in a lake. Its addition is the cause of accelerated eutrophication in most lakes, due to the aggressive nature of algae in taking it up. It is relatively immobile in the terrestrial soil and is slow to leach unless the soil has reached its carrying capacity. The major inputs of phosphorus into the lake are precipitation, erosion and sediments, over-fertilization, and cleaning products containing ortho-phosphate (PO_3^{3-}).

Although phosphates in detergents have been banned in Michigan since 1977, many of the products which claim not to contain phosphorus, still do.[42] Ortho and poly-phosphates are the forms most commonly found in most synthetic detergents which contain phosphorus.[23] It has been estimated that three grams of phosphate are produced per day per person in raw sewage, and that over-fertilized lawns and other sources account for one gram per household per day.[53]

Concentrations <5-15 parts per billion ppb of phosphorus entering a lake are considered to be safe levels, 20-40 ppb are considered high amounts, and at 80 ppb phosphorus is not a limiting element for any photosynthesizing organism.[70]

Phosphorus enters lakes in three main forms: 1) Orthophosphate ($H_2PO_4^-$, $HPO_4^=$, PO_4^{3-}) and polyphosphate ($Na(PO_3)_6$)6; 2) Soluble organic phosphates; and 3) particulate organic phosphate. Together these equal total phosphorus.[69]

Phosphorus can enter a body of water through septic systems, positively charged dust particles carrying negatively charged phosphates, eroding minerals, runoff of fertilizers, atmospheric precipitation, and wildfowl waste. See Figure 27. When phosphorus enters the water body, it is likely to be used immediately by algae. When the algae dies it sinks to the bottom sediment where it will remain until it is eaten as detritus or taken up by rooted plants. Plants continually take up as much phosphorus as is available to them. When they can not use any more, they will then excrete the excess through their foliage. In well oxygenated water the free phosphates (PO_4^{3-}) in solution become tied with heavier elements such as Iron ($FePO_4$) and sink to the bottom sediment. When the conditions become anoxic in this bottom substrate, the bond breaks between the iron and phosphate, and the phosphate becomes available for uptake. When the water mixes, the phosphates are distributed throughout the water column.[70] This is generally why algal blooms occur right after the spring overturn.

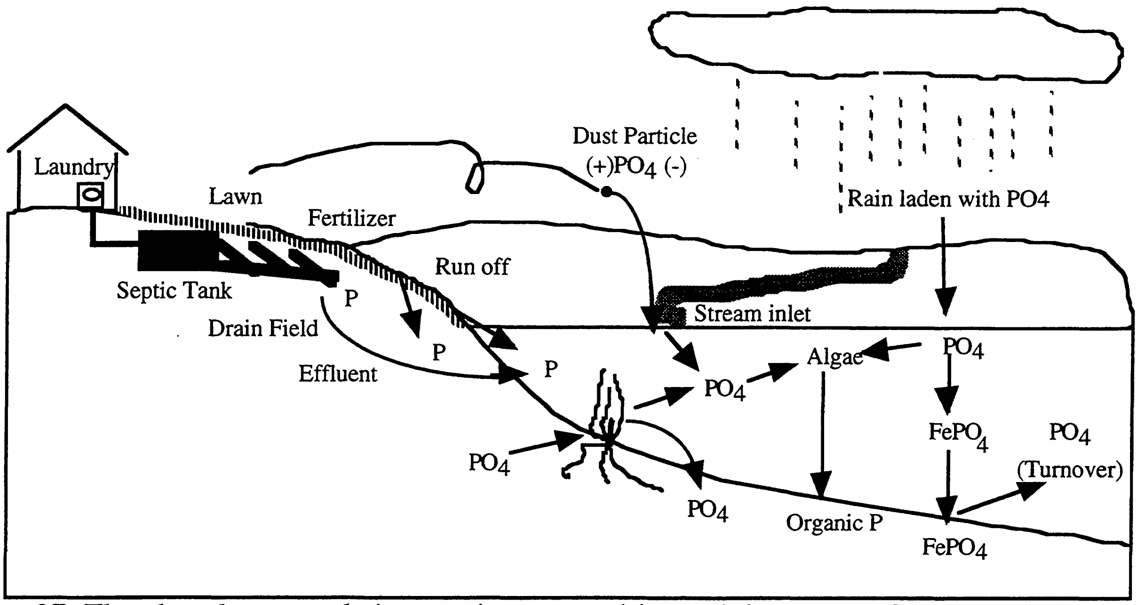


Figure 27: The phosphorus cycle in aquatic communities and the sources for it entering a lake.

Lime Lake total phosphorus data was collected May 2, 1978, August 26, 1980, and throughout 1991 and 1992, each time at three depths. Figure 28 shows the total phosphorus on each date. In both 1991 and 1992, the highest phosphorus levels were in mid summer when most people use their cottages. If one were to try to compare the historical data with the current data, the results might be misleading, since there are only two dates in separate months. In comparing May data, the amount of total phosphorus is significantly higher on May 2, 1978 than it is on May 15, 1991, or May 6, 1992. This may be accounted for by more spring fertilization of agricultural lands at that time. When comparing data from August 26, 1980, August 20, 1991, and August 25, 1992, there is a greater jump in the amounts of total phosphorus in the two more recent years which may correlate with an increase of newer homes around the lakes.

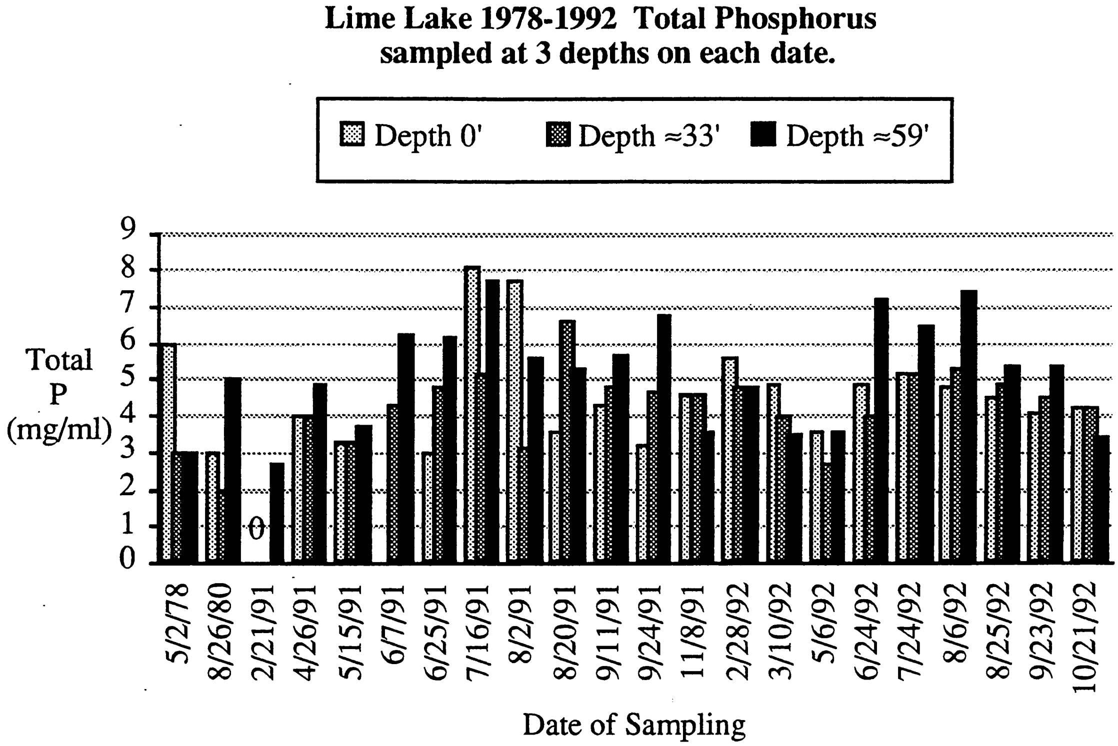


Figure 28: Lime Lake total phosphorus at each depth.

Little Traverse Lake was not tested for total phosphorus prior to 1991. The results for 1991 show high amounts of phosphorus in February which decline in the spring, and increase dramatically in mid-summer. This is shown in Figure 29.

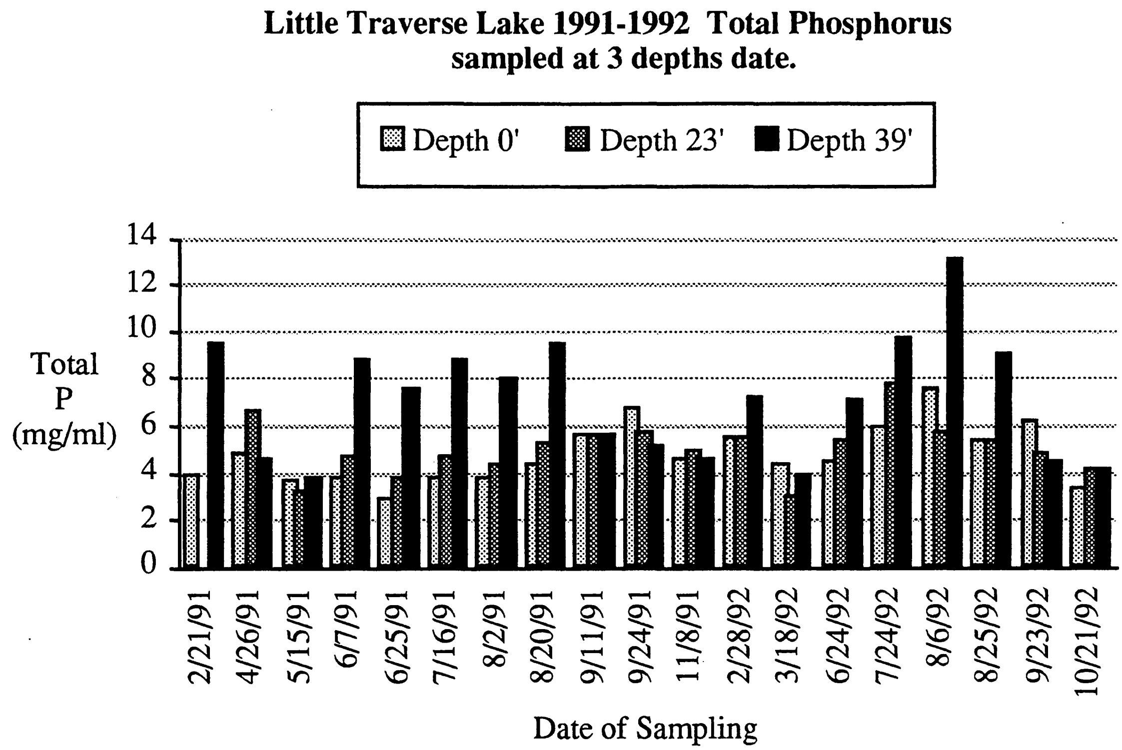


Figure 29: Little Traverse Lake total phosphorus at each depth.

d. Chlorophyll *a*

Chlorophyll *a* measures the amount of photosynthesis, mostly algal production, occurring in a water column. Previous to 1993, Lime Lake had been tested twice for chlorophyll *a*, May 2, 1978 and August 26, 1980. Little Traverse Lake had never been tested.

Chlorophyll *a* is one of the measures used in Carlson's Trophic State Index to determine the trophic state of lakes as discussed in detail under the heading Trophic State Index from Secchi, Phosphorus, Chlorophyll *a*.

e. Trophic State Index from Secchi, Phosphorus, and Chlorophyll *a*

Carlson's scale is simple and easy to use for correlating three commonly used measurements taken in lakes: secchi disc visibility in meters measures water transparency; total phosphorus in mg/m^3 measures a limiting nutrient; and chlorophyll *a* in mg/m^3, uses an element in photosynthesis as a measure of algal content. All three tests should be performed to determine which will give the best representation of what is happening in the lake. Once the optimal test or tests are determined, they should be used for the TSI. Each of Carlson's three formulas produce a value between 0 and 100.[9] The Michigan Department of Natural Resources MDNR considers lake values less than 38 to 40 as oligotrophic, values over 48 to 52 as eutrophic, and values in-between as mesotrophic.[42] Measurement values from water testing can be transferred into this 0-100 scale by the following equations: [9]

$$\text{TSI (SD)} = 10\left(6 - \frac{\ln \text{SD}}{\ln 2}\right), \quad (1)$$

$$\text{TSI (Chl)} = 10\left(6 - \frac{2.04 - 0.68 \ln \text{Chl}}{\ln 2}\right), \quad (2)$$

$$\text{and TSI (TP)} = 10\left(6 - \frac{\ln \frac{48}{\text{TP}}}{\ln 2}\right). \quad (3)$$

The first equation transfers the secchi disc measurements into TSI values. The secchi disc method is used almost exclusively now by the MDNR in its Inland Lakes Management Program (ILMP) for lake associations throughout the state to measure the trophic state of their lakes.[42] This measurement used alone can give skewed indications of biological productivity due to materials reducing visibility in the water column which are not due to algal productivity.

The second equation uses the results of the chlorophyll *a* measurements to produce a TSI value.[9] This test is expensive [42] and its accuracy as an indicator of productivity is best only in the summer months.[9]

The third equation converts the total phosphorus into a TSI value. An assumption associated with this value is that phosphorus is the element which is most needed for more algal production to occur in the lake. Most lakes in Michigan do not have enough phosphorus in the water to support all of the potential algae that could be in the water column. When phosphorus is added to the water it is quickly absorbed by algae which reproduces prolifically, hence, phosphorus is generally considered the limiting element in Michigan lakes. The best time for these measurements is in the spring, fall, and winter when something other than phosphorus is the limiting element.[9]

Table 7: The ideal relationships of the three measurements to the trophic index.[9]

Completed TSI scale and its associated parameters			
TSI	Secchi disk (m)	Surface phosphorus (mg/m^3)	Surface chlorophyll (mg/m^3)
0	64	0.75	0.04
10	32	1.5	0.12
20	16	3	0.34
30	8	6	0.94
40	4	12	2.6
50	2	24	6.4
60	1	48	20
70	0.5	96	56
80	0.25	192	154
90	0.12	384	427
100	0.062	768	1183

As can be seen in Table 8, the secchi disc values are inconsistent from the 1990 to 1992 data and the data from 1993. The first data would indicate that both Lime and Little Traverse Lakes are mesotrophic, while the second set of results place both lakes in an oligotrophic state. In both lakes there are high concentrations of marl ($CaCO_3$) being produced in the water column which may reduce visibility and make the values of the secchi disc reading lower.[9]

The Leelanau Conservancy combined all of the results which they received for chlorophyll *a* throughout the year. Our project group recalculated the data consistent with Carlson[9], and received similar results as seen in Table 8. Chlorophyll *a* data from 1993 place both lakes in a mesotrophic state. The historic data is too sparse to be used for any comparisons. It would be assumed that the chlorophyll *a* data is the best determinant of trophic status, since this measures the actual amount of algae.

The Leelanau Conservancy combined all of the results which they received for total phosphorus throughout the year and at all depths. Our project group recalculated the data consistent with Carlson[9], and received similar results as seen in Table 8. All of the total phosphorus measurements place both lakes in an oligotrophic state.

Table 8: Information from the Leelanau Conservancy showing the relationship of secchi disc values, total phosphorus, and chlorophyll *a*, as data averaged from 1990 to 1992. Also the TSI values are shown as calculated by the conservancy and by the project group combined from 1990 to 1992, and from the 1993 data.

Parameter	Little Traverse Lake		Lime Lake	
	Conservancy Values	Project Group Values	Conservancy Values	Project Group Values
1990 -1992 data				
Secchi (m)	3.0		2.9	
Total P (ug/L)	5.7		4.7	
Total N (ug/L)	116		209	
Chlorophyll-*a*	n/a		n/a	
TSI secchi disc	44	44	45	45
TSI total P	29	27	26	25
TSI chlor-*a*	n/a	n/a	n/a	n/a
1993 data				
TSI secchi disc	26	26	24	24
TSI total P	28	25	22	22
TSI chlor-*a*	40	40	38	39

f. Nitrogen

Most lakes will naturally have sufficient amounts of nitrogen as needed by all organisms for either photosynthesis or protein production. Plants use 16 to 17 times as much nitrogen as phosphorus.[70] Certain forms of nitrogen can be dangerous if the levels are too high.

Nitrates (NO_3) are the most soluble form of Nitrogen. It is the form most often found in lawn and farm fertilizers, as it is easy for plants to intake. Due to its solubility it is quickly leached through the soil and into the groundwater. Groundwater which feeds a lake can carry nitrates into the lake and could possibly cause levels too high for human usage. Levels of NO_3 in the water exceeding 10 mg/l (ppm), or sometimes expressed as 45 mg/l nitrate nitrogen [46], are above the Environmental Protection Agency (EPA) drinking water standards. Extreme levels can induce nausea and vomiting, and cause the Blue-baby syndrome (Methemoglobinemia) in pregnant women or children under the age of six months.[38]

Ammonia (NH_4) in the aquatic environment can be toxic to fish. This substance is found in many fertilizers and in many household cleaners which may pass through septic systems. Natural sources of NH_4 occur in lakes from excretions of aquatic animals and as the end product of many bacteria.[69] In well oxygenated aquatic environments, these levels rarely are high enough to cause damage unless the outside sources are severe.

Other forms of Nitrogen are Nitrites (NO_2), and Nitrogen dissolved from the atmosphere (N_2).These forms are relatively safe to the aquatic environment and to humans.

In the aquatic environment Nitrogen can change forms, as shown in the Nitrogen cycle in Figure 30.

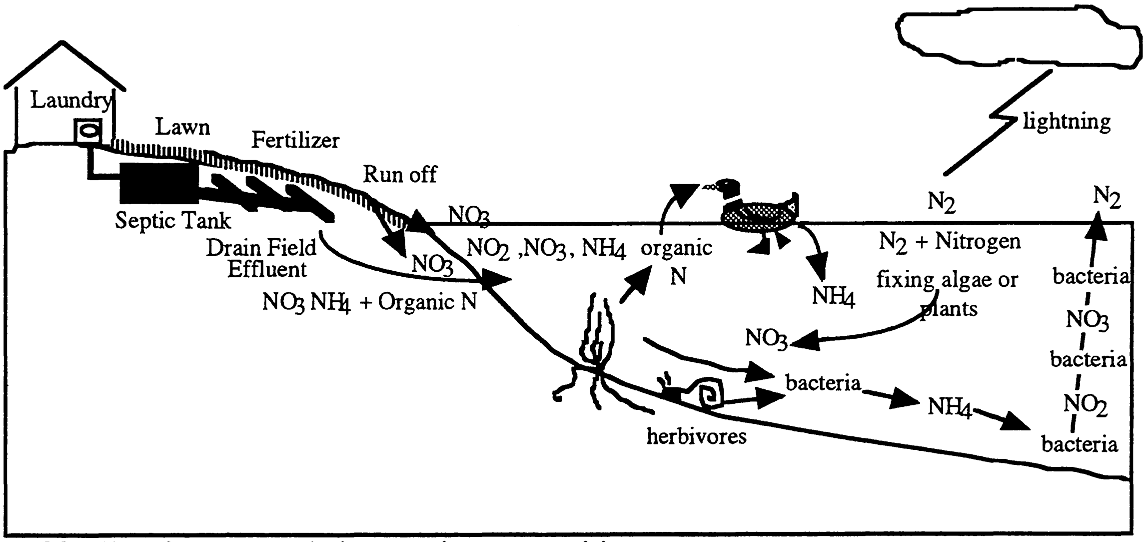


Figure 30: The nitrogen cycle in aquatic communities.

Only two tests for nitrates and nitrites were performed on Lime Lake prior to 1991, and none on Little Traverse Lake. Only three dates were tested in 1991 on each lake. Both lakes have erratic readings.

Lime Lake data is in Figure 31. The total nitrate and nitrite levels fluctuate throughout most of 1992, but they seem to drop off dramatically after August. This may correspond to a reduction of human population after Labor Day. There are more nitrates and nitrites on May 2, 1978 than May 6, 1992. August 26, 1980, August 20, 1991, and August 25, 1992, show varying levels, leading to no conclusions.

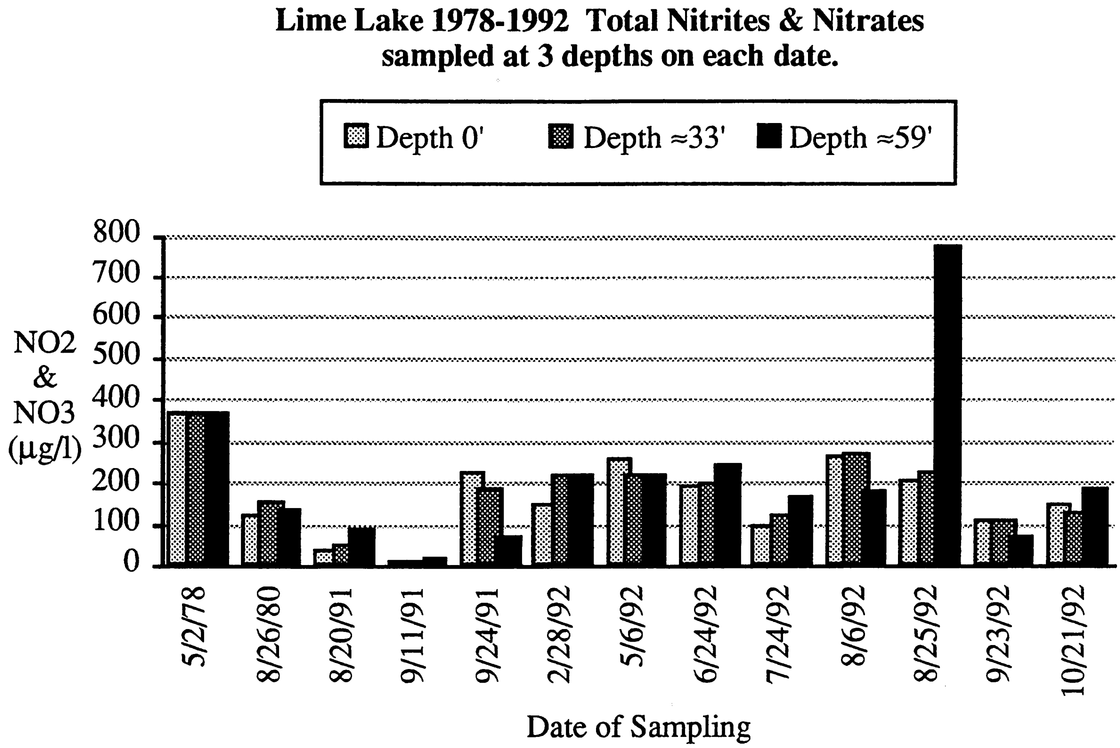


Figure 31: Lime Lake total nitrites and nitrates at each depth.

The data for Little Traverse Lake is shown in Figure 32. The data is too sparse to warrant conclusions.

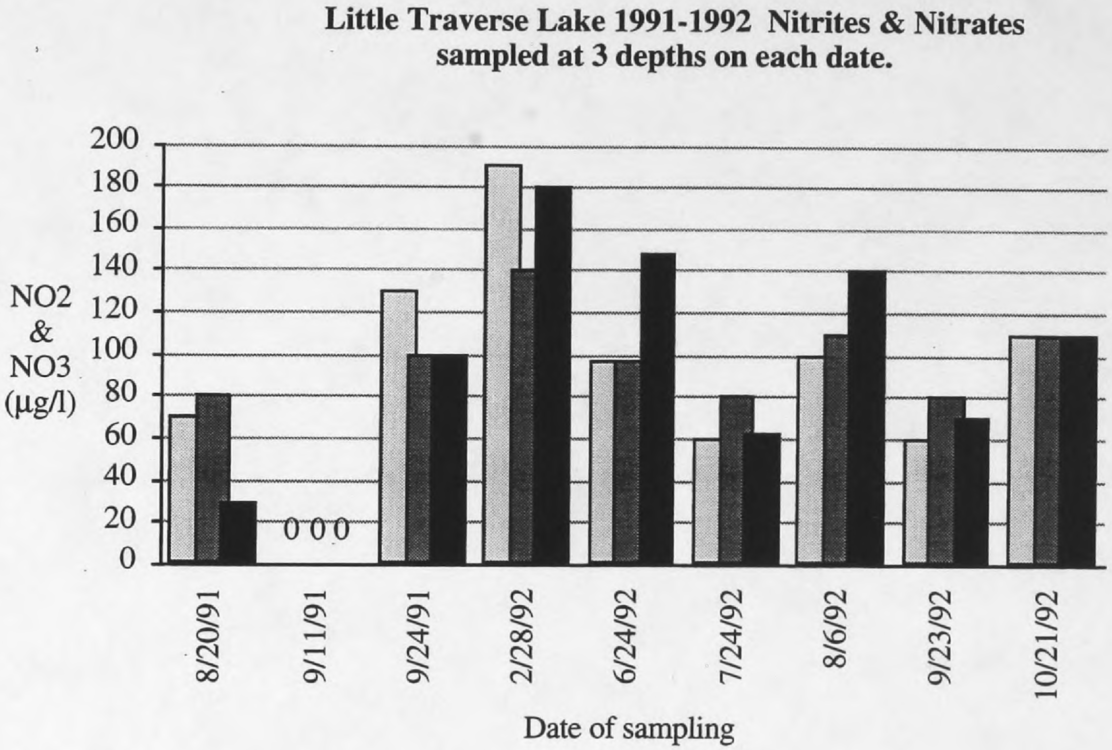


Figure 32: Little Traverse Lake total nitrites and nitrates at each depth.

g. Nutrient Budget

The Leelanau Conservancy, in conjunction with Bill Cutler from the MDNR, have started to monitor the inflowing and outflowing waters of Lime and Little Traverse Lakes to start a nutrient budget. Their preliminary findings can be found in Table 9.

Table 9: Data compiled by Bill Cutler for the start of a nutrient budget.

Lime Lake			
Source	Total phosphorus μg/g	Pounds / year	Percent of total
Stream	8.3	80	13
Groundwater	7.5	103	17
Bulk precipitation	73	430	70
Total		613	
Little Traverse Lake			
Source			
Stream	6.3	189	28
Groundwater	11.5	77	12
Bulk precipitation	73	402	60
Total		668	

There are a few different formula's given by Wetzel[69] to determine nutrient loadings in lakes. The data supplied to us does not give the outputs of phosphorus which is needed in the formula's.

h. pH

The pH is the measure of Hydrogen (H^+) or Hydroxyl (OH^-) ions in the water. The scale is from 0 to 14. Zero is the most acid (H^+ ions only), 14 is most alkaline (OH^- ions only), and 7 is neutral (equal amounts of H^+ and OH^- ions). PH is measured in a logrithmatic scale, therefore, for each whole number change in pH, there is a 10 times increase or decrease. For example, a change in pH from 7 to 9 is 100 times more basic.[27] Most organisms can survive in only a relatively narrow pH range.

Surface waters in the state of Michigan are required to remain in a range between 6.5 to 9. This is due to the fact that many ecosystems are damaged below a pH of ±6, and that reproduction of most fish cease near a pH of 5.3 to 5.6. Lakes below a pH of 5.0 become relatively lifeless.[42]

Michigan was formed on a parent material of limestone, which is rich in Calcium (Ca). This is fortunately able to buffer the acidity entering most lakes, especially from acid rain.[42] In 1986, the precipitation findings in Empire, Michigan were found to range between 3.5 to 4.6, having a logarithmic average of 4.0. Rain-water unaffected by pollution is determined to have a pH of ±5.6, therefore all of the rain measured that year is considered acidic.[39]

The pH data on Lime and Little Traverse Lakes indicate that the water has very good capacity to buffer the acid rain. Plant photosynthesis removes Carbon Dioxide (CO_2) from the water column during sunlight hours in the summer, creating a diurnal cycle. Since CO_2 acts as an acid, its removal raises the pH.[20]

The pH can also directly alter the forms in which dissolved carbon gas can occur. The forms in which Carbon can be dissolved in an aquatic environment are Carbon Dioxide (CO_2), Carbonate ($CO_3^=$), and Bicarbonate (HCO_3^-). At pH 8.3, bicarbonate is the predominant form of carbon gas. As the pH rises, carbonate becomes the predominant form, and as the pH becomes more acidic carbon dioxide increases.[53] The form of Phosphorus can also be determined by the pH. This is in Table 10.

Table 10: The most common form of phosphorus at given pH ranges.[51]

Form of P	pH range in which form occurs
H_3PO_4	1-4
$H_2PO_4^-$	2-7
$HPO_4^=$	7-12
PO_4^{3-}	12-14

Both Lime and Little Traverse Lakes have very good pH range. There appears to be a correlation between pH and DO. In general, the waters with less DO are slightly more acidic than that of the well oxygenated waters.

In Lime Lake throughout 1990 the epilimnion pH remained around 8.3, while the hypolimnion became 7.4 at its most acidic. 1991 had much more variation in the pH range, perhaps due to two measurements earlier in the year than in 1990. Figure 33 and Figures 34a through 34e show the changes which occurred in 1991. At the beginning of the year the pH was near 8.0 at the surface and as low as 7.5 near the bottom. On April 26, after the spring overturn, the pH rose only to 8.15, and climbed only to 8.2 by May 15. On June 7 there is a significant curve forming in the graph. On this date there is also an extreme rise in the pH at the depth of 39 feet, apparently due to a mistake in the data. The pH in the epilimnion fluctuated between 8.1 to 8.2 throughout the rest of the year until it settled on 8.1 after the fall overturn.

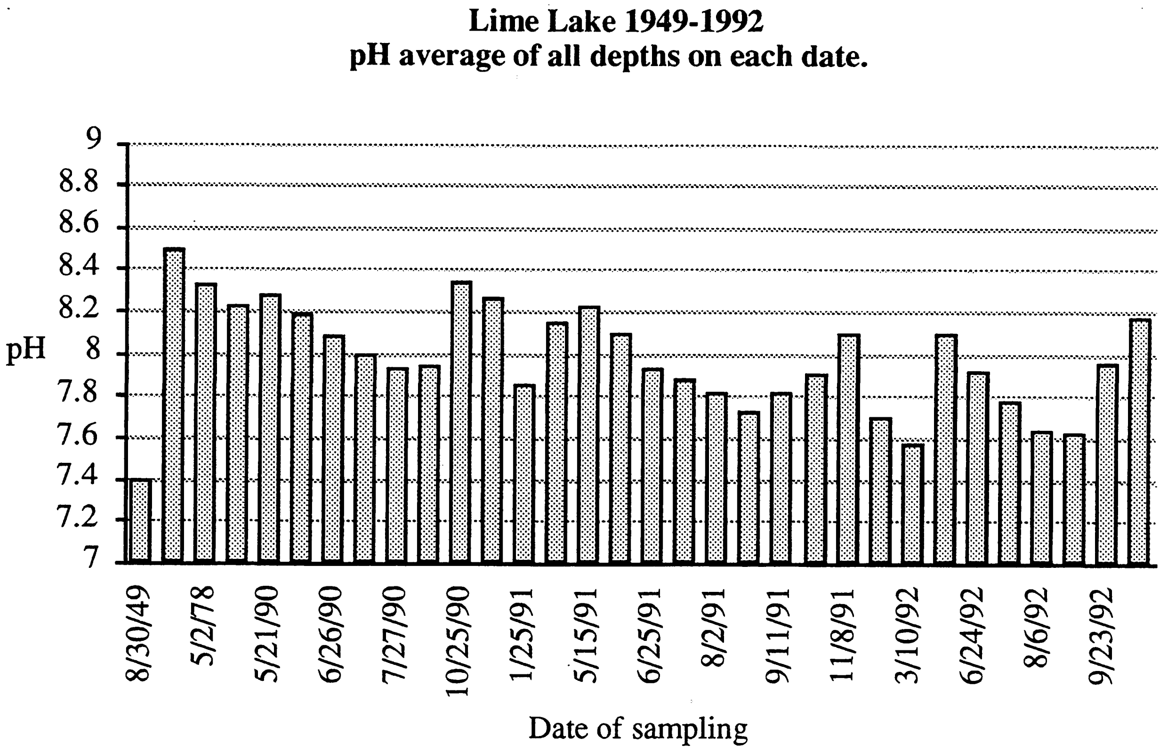


Figure 33: Lime Lake pH measurements.

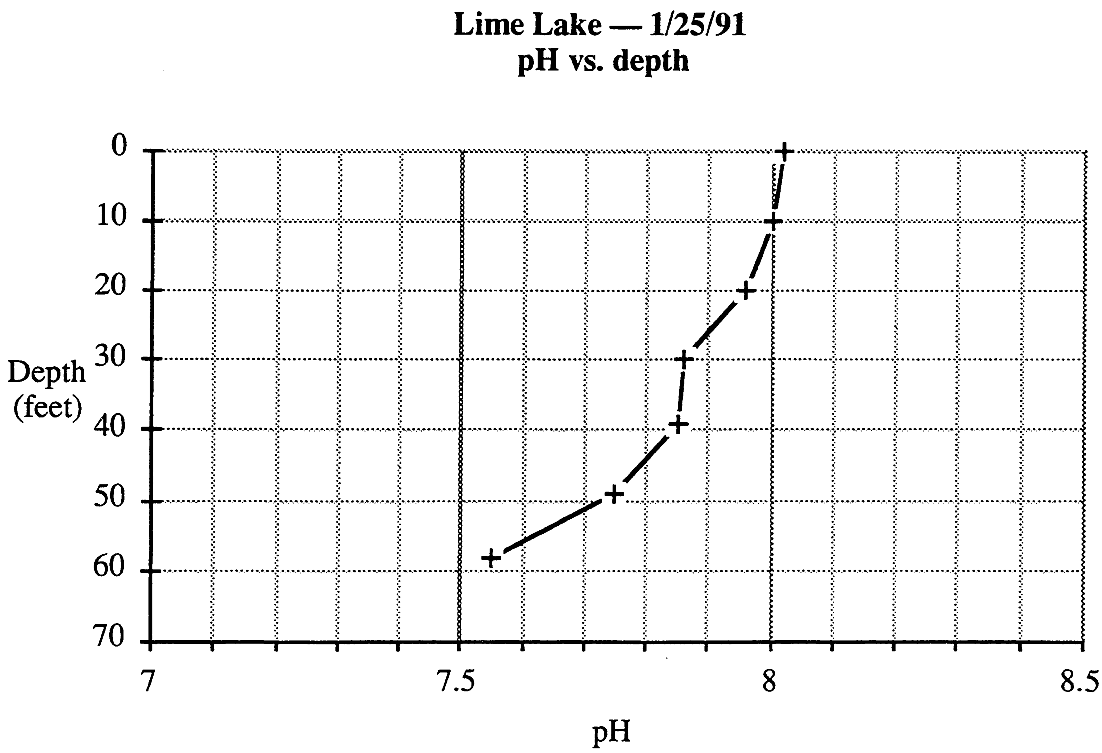


Figure 34a: Lime Lake pH measurements.

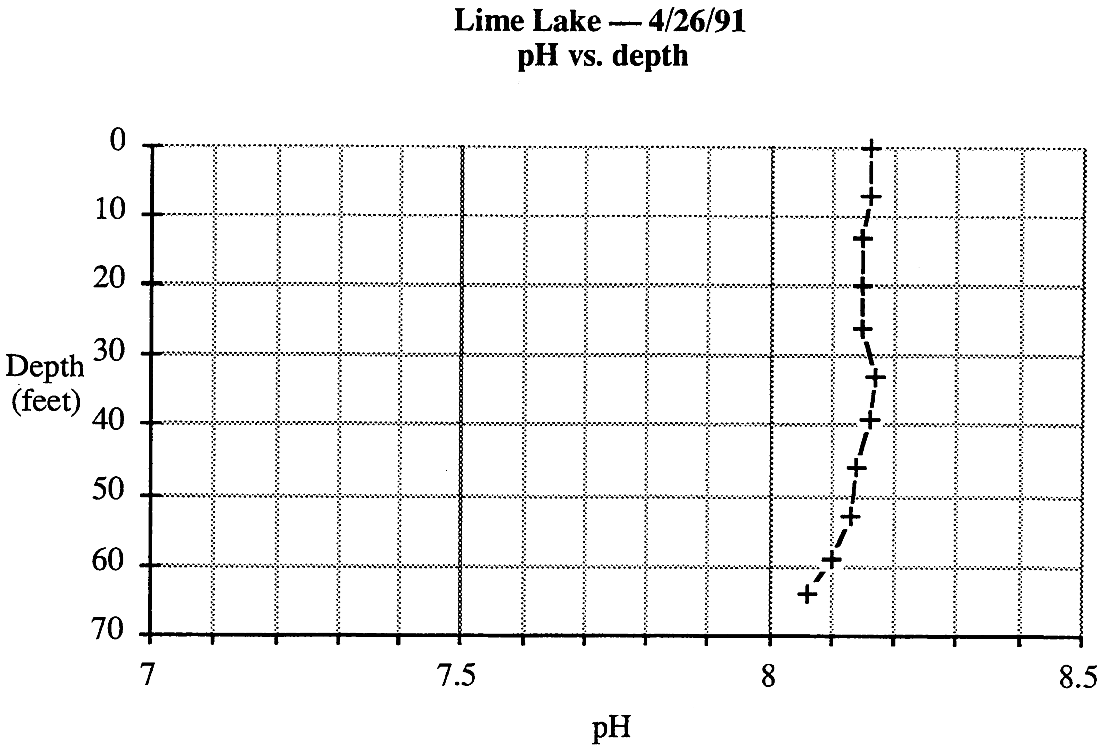


Figure 34b: Lime Lake pH measurements.

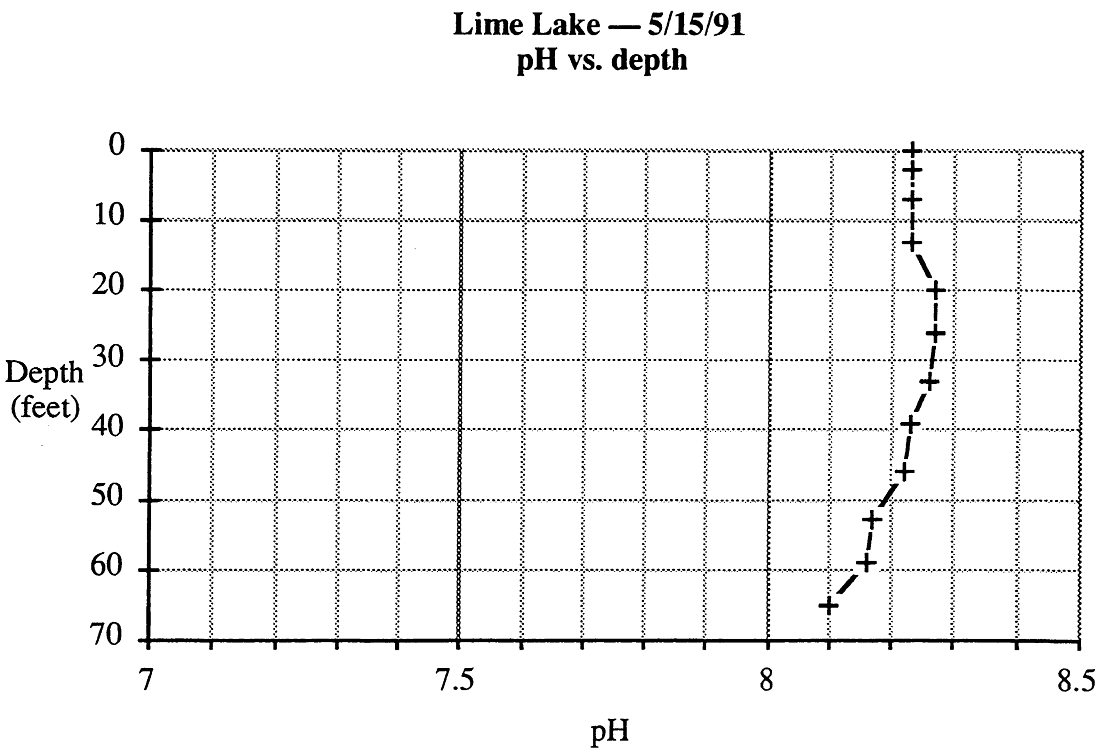


Figure 34c: Lime Lake pH measurements.

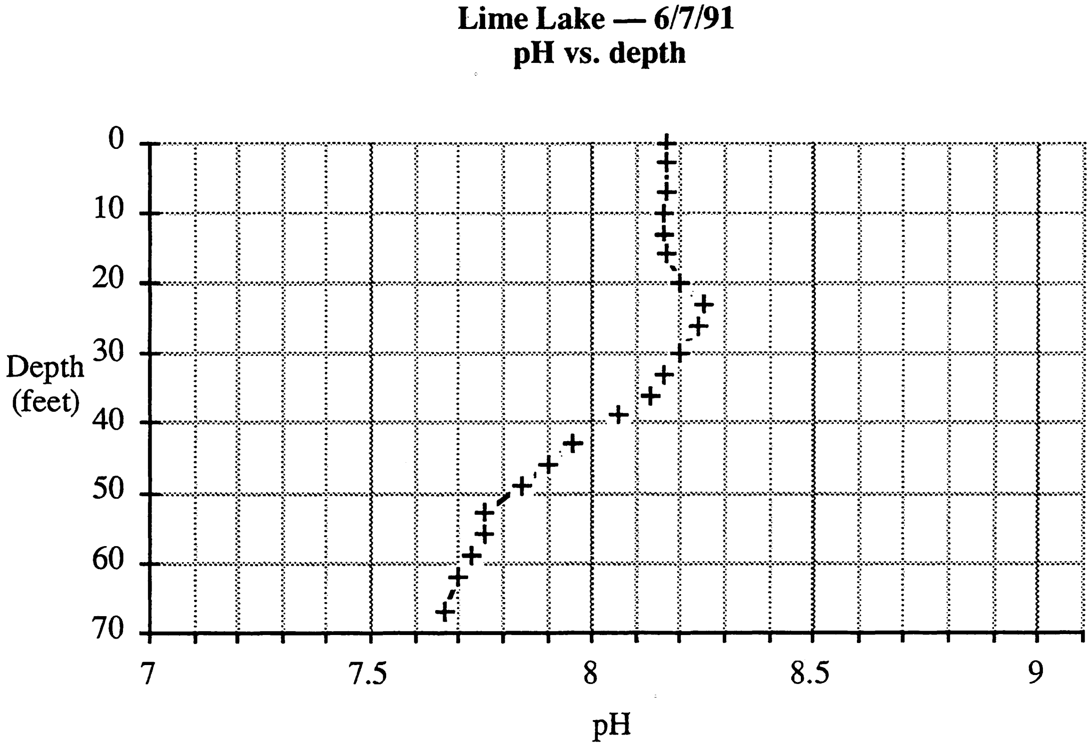


Figure 34d: Lime Lake pH measurements.

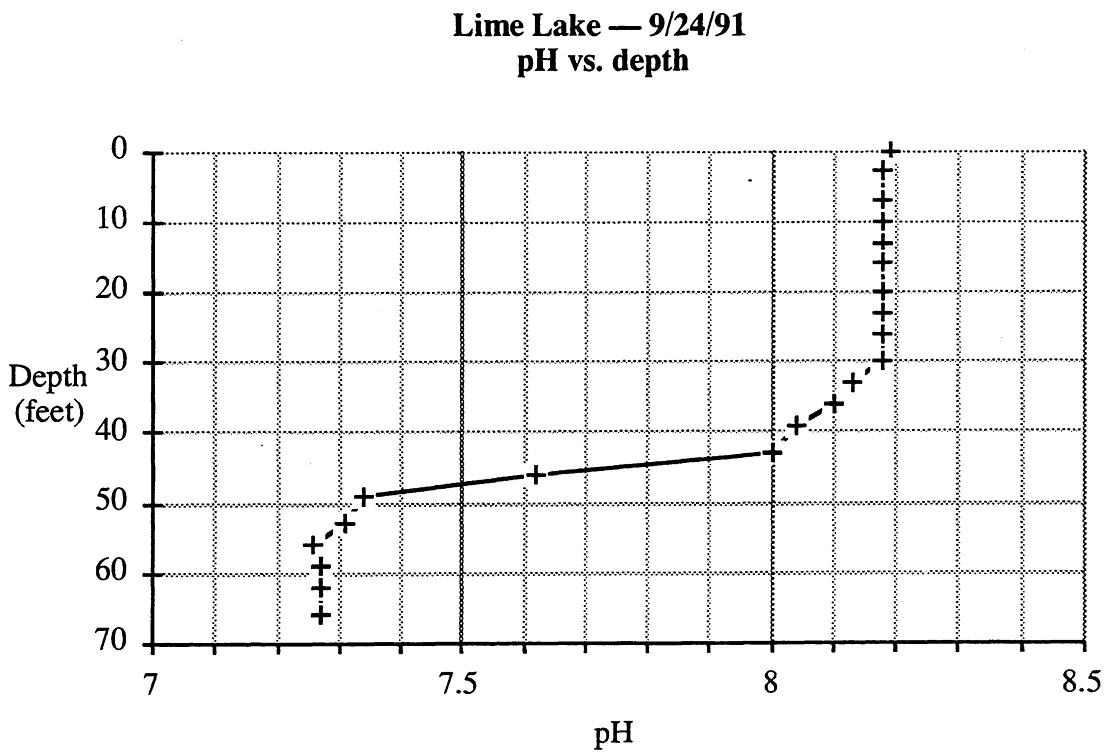


Figure 34e: Lime Lake pH measurements.

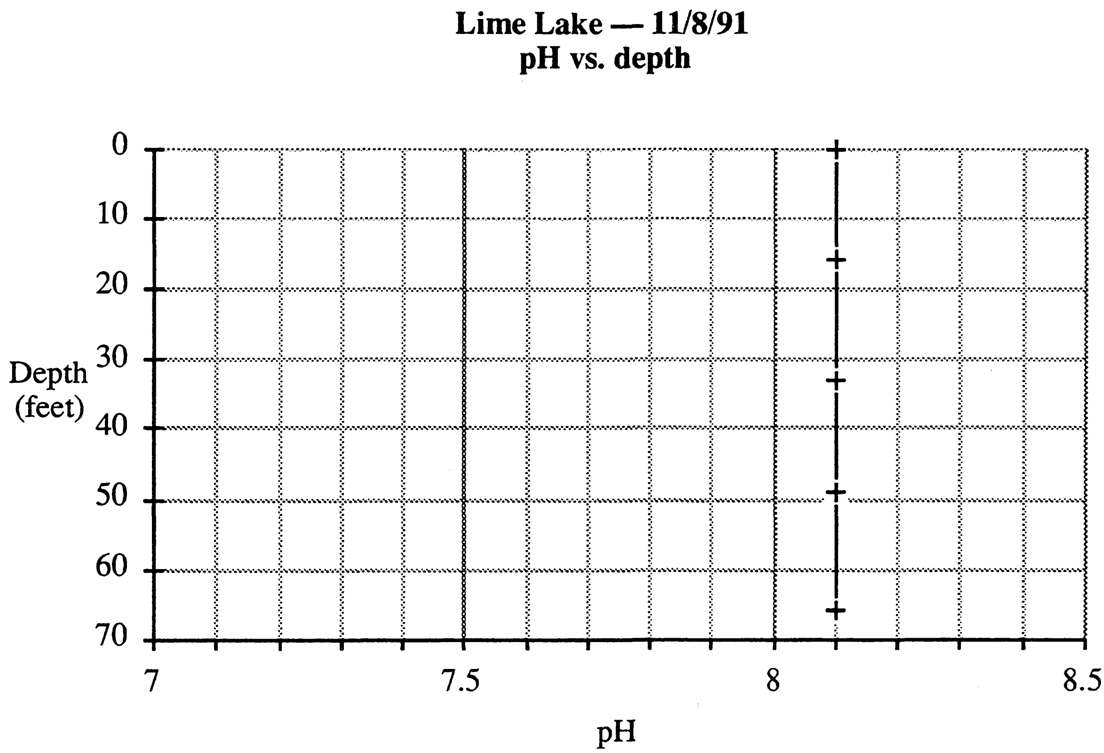


Figure 34f: Lime Lake pH measurements.

In 1992 the pH range was greater, apparently due to a new measurement taken on March 10 when the pH had dropped to 7.7 at the surface. After the spring overturn the pH generally ranged between 8.1 to 8.2, remaining at 8.2 after the fall overturn. The most acidic the water became near the bottom was pH 7.2 on September 23.

The pH data for Little Traverse Lake correlates with the data for Lime Lake, as seen in Figure 35. There are only slight variations between the 1991 and 1992 graphs.

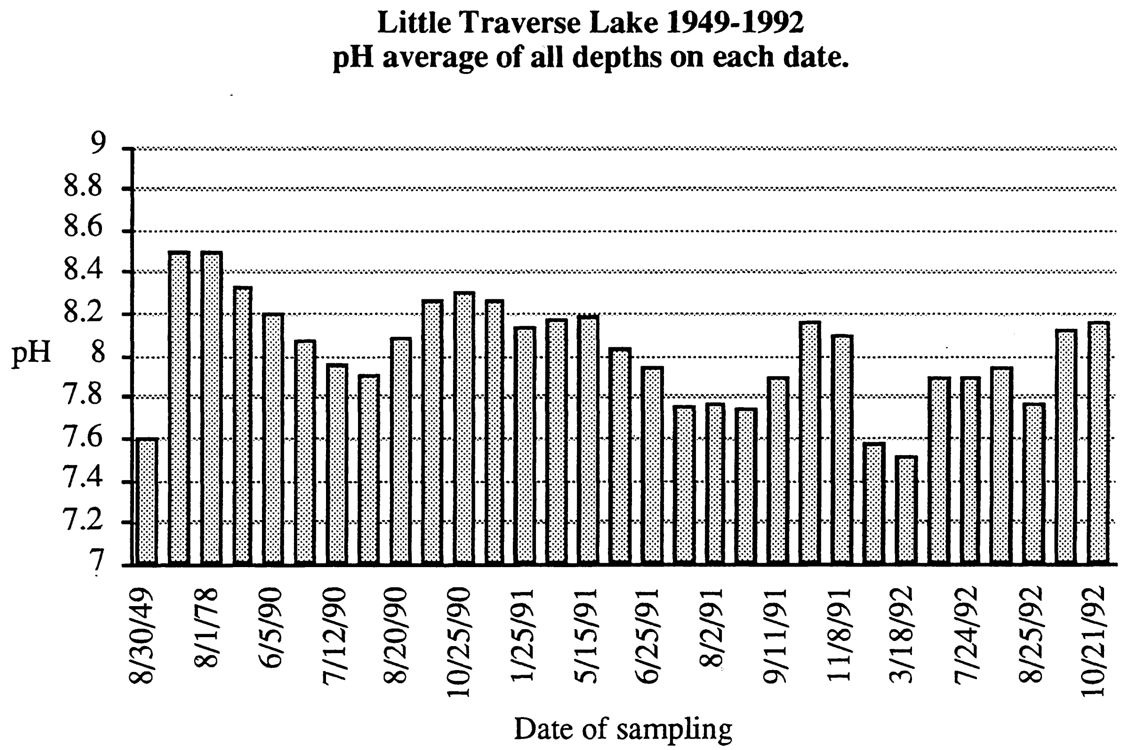


Figure 35: Little Traverse Lake pH measurements.

Although there seems to be a slight drop in pH from 1990 to the following years, there is no danger to the pH of either lake from acid rain or other causes.

i. Conductivity

Conductivity is a measure of charged particles in the water, having the ability to conduct an electrical current. The test measures ions, but it does not measure dissolved organic matter, nor does it differentiate between ions with high conductance as opposed to low conductance.[70] Over-abundance of ions dissolved in the water column usually indicates water quality in decline.[20]

Conductivity is a general test of many substances. During a study of waterfowl habitat in Utah, levels of conductivity as well as salinity were rated in Table 11 below.

Table 11: Rating of conductivity for waterfowl habitat.[49]

Rating	Conductance in mmhos
Excellent	<1
Good	1-2
Fair	2-4
Poor	4-8
Restrictive	>8

Data from Lime and Little Traverse Lakes indicate that conductivity levels remain generally good. The concentrations of conductive materials seem to correlate with the time of year and also somewhat to stratification. The concentrations are generally slightly higher in the hypolimnion than the epilimnion. This could be due to the seasonal changes in calcium and HCO_3^- A direct correlation exists between the concentration of these ions and the conductance of hard-water lakes in the epilimnion. Often the concentrations of calcium carbonate $CaCO_3$ will remain in solution and cause greater readings.[69]

Figures 36a through 36i of Lime Lake show slightly rising average concentrations throughout the three years tested. The conductivity ranged from approximately .26 to .30 in 1990. The largest increase was prior to June 25 when the surface measurement jumped from the previous .28 up to .30. This might be explained by increased occupation of cottages and stirring up the sediments through recreation. In 1991 the range was greater, from .25 to .30 at the surface. After the fall overturn, the conductivity remained at .30 throughout the rest of the year and into the beginning of 1992. The conductivity dropped to .187 at its lowest on March 10, but jumped to .316 on May 6. It stayed at approximately this same surface value throughout the rest of the year, which is higher than the previous years had been.

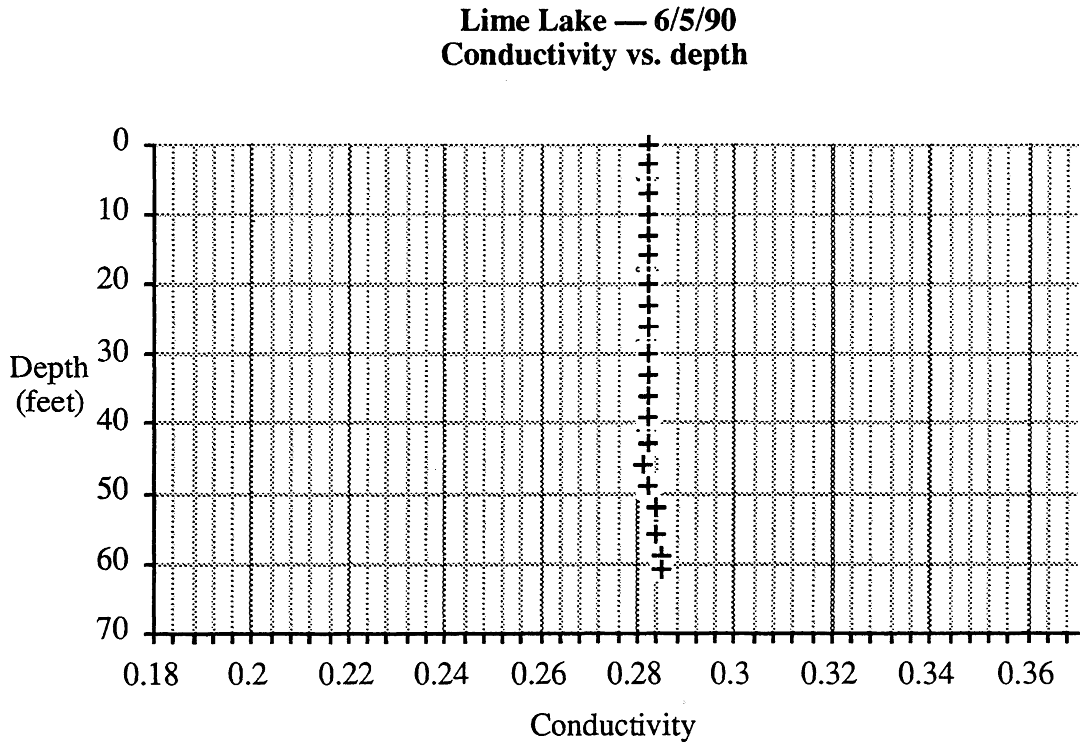


Figure 36a: Lime Lake conductivity measurements.

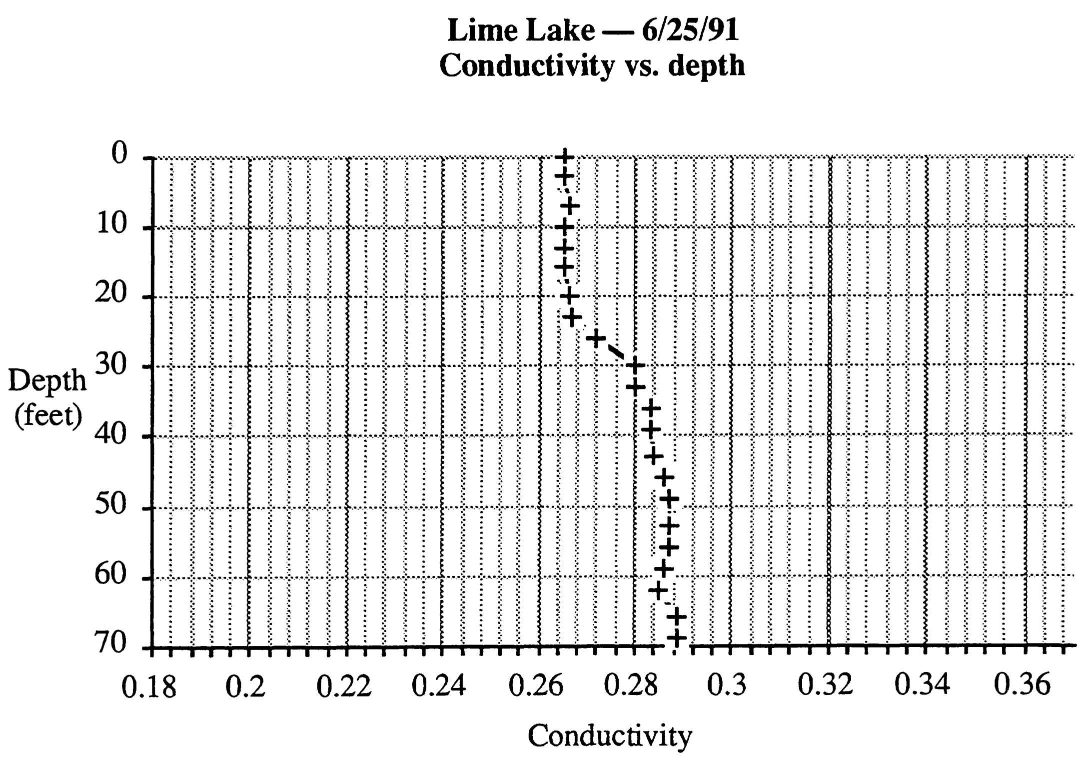


Figure 36b: Lime Lake conductivity measurements.

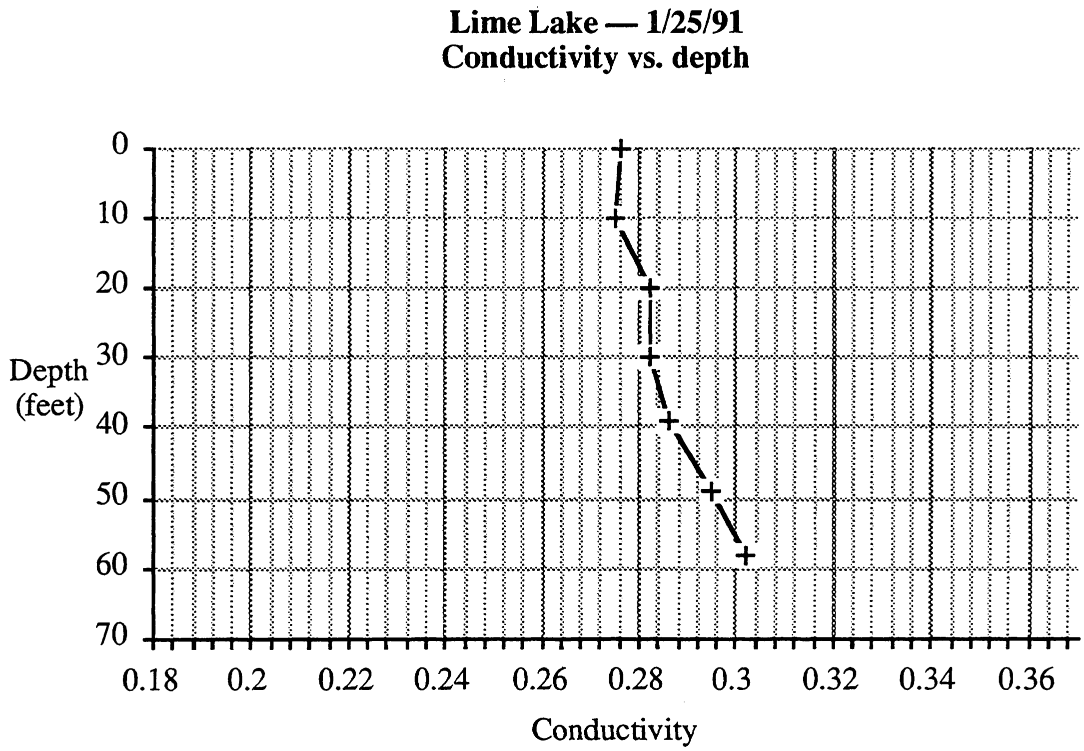


Figure 36c: Lime Lake conductivity measurements.

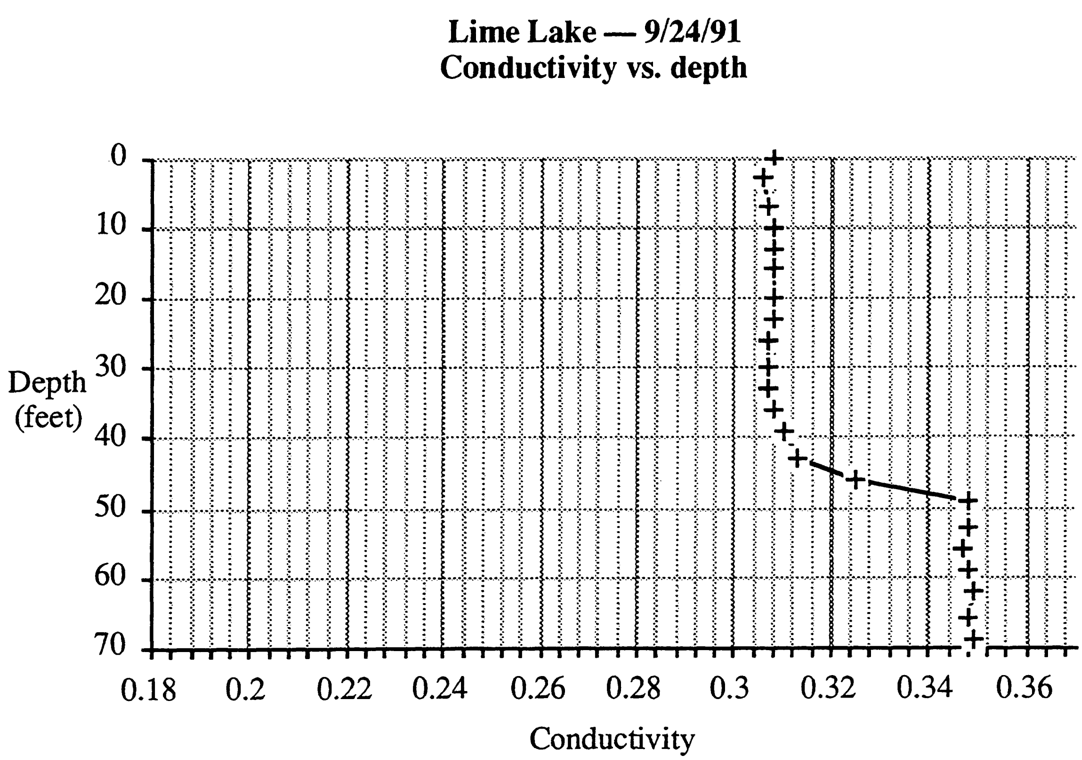


Figure 36d: Lime Lake conductivity measurements.

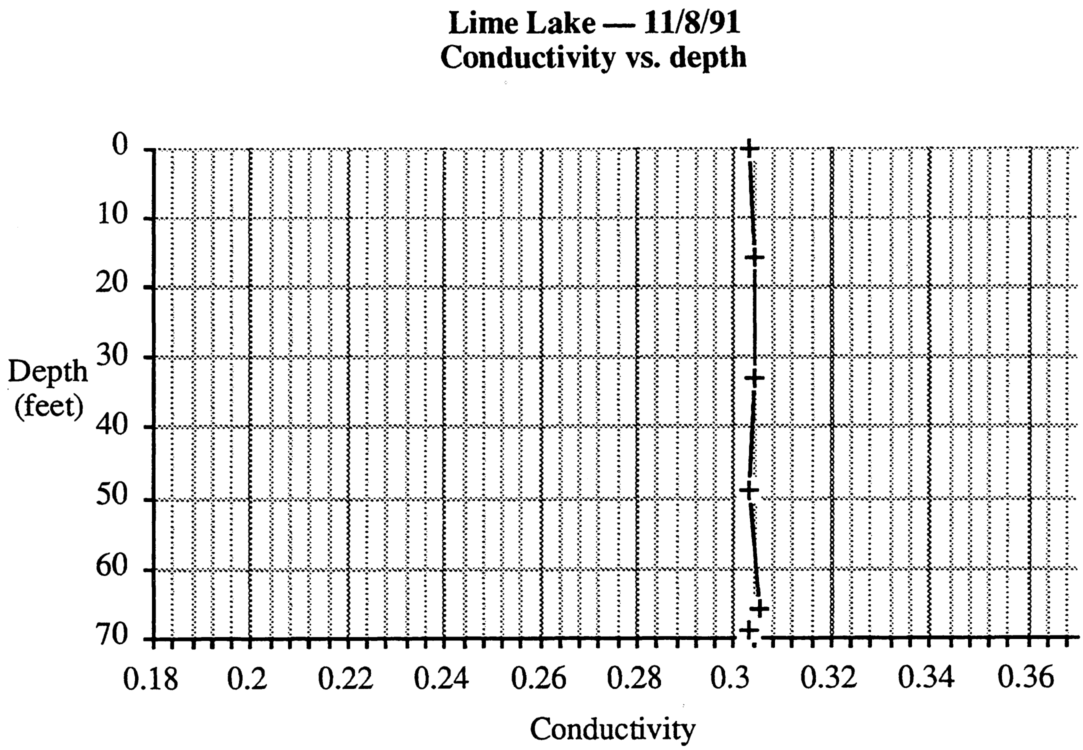


Figure 36e: Lime Lake conductivity measurements.

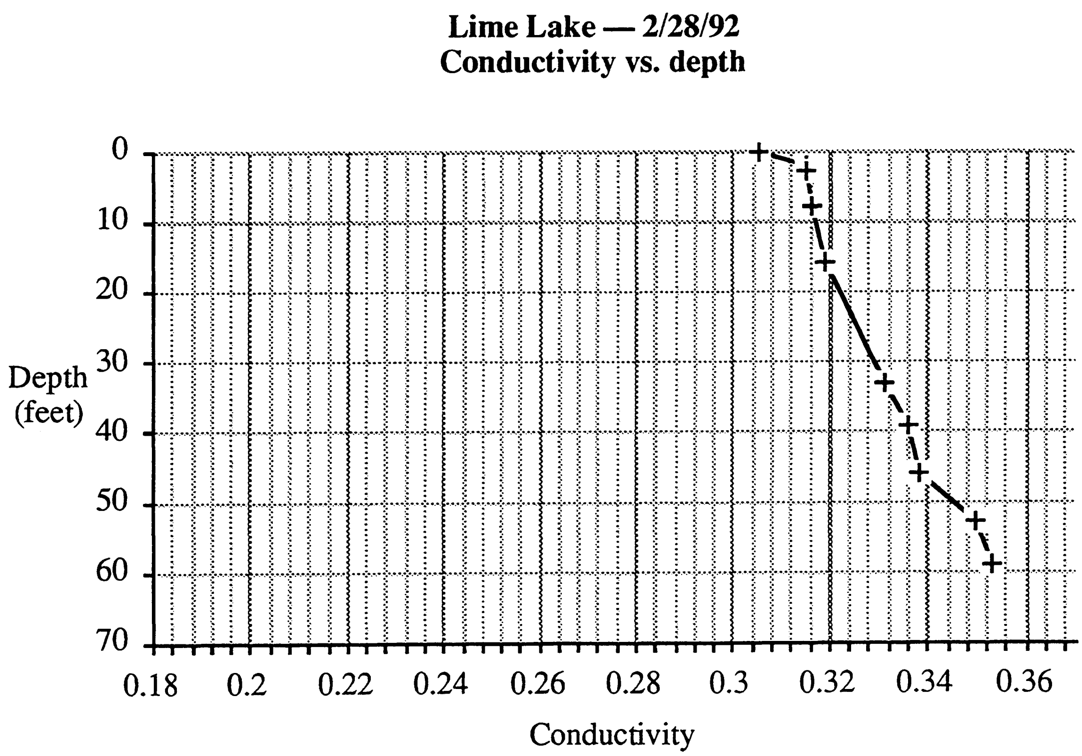


Figure 36f: Lime Lake conductivity measurements.

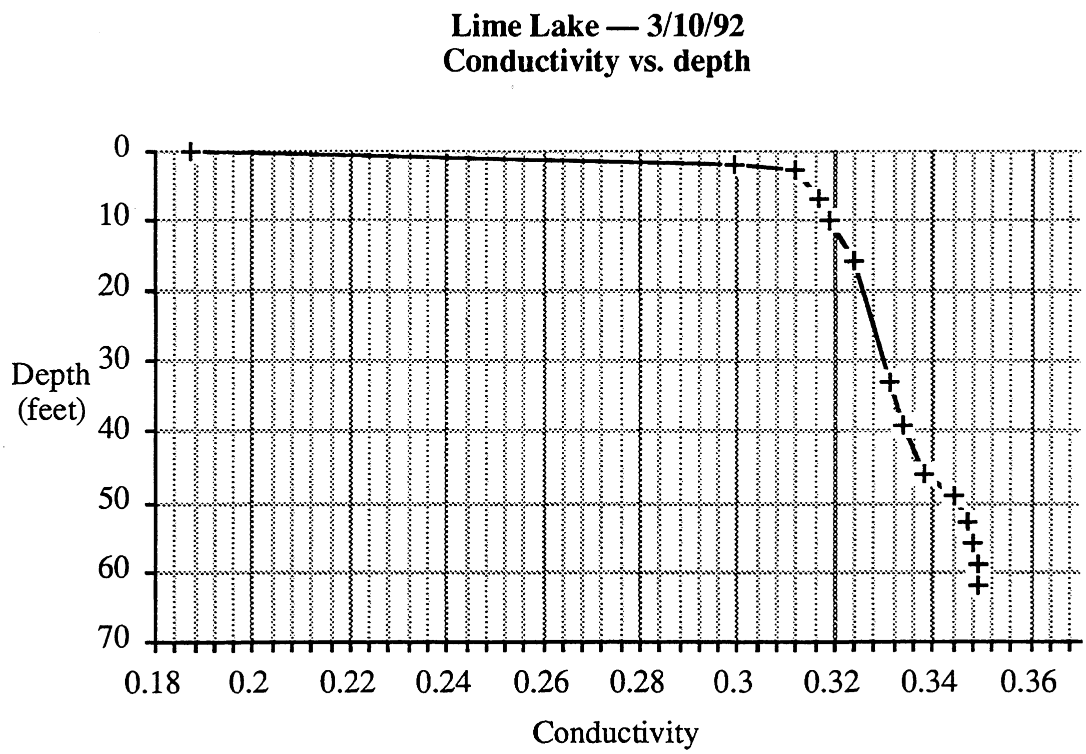


Figure 36g: Lime Lake conductivity measurements.

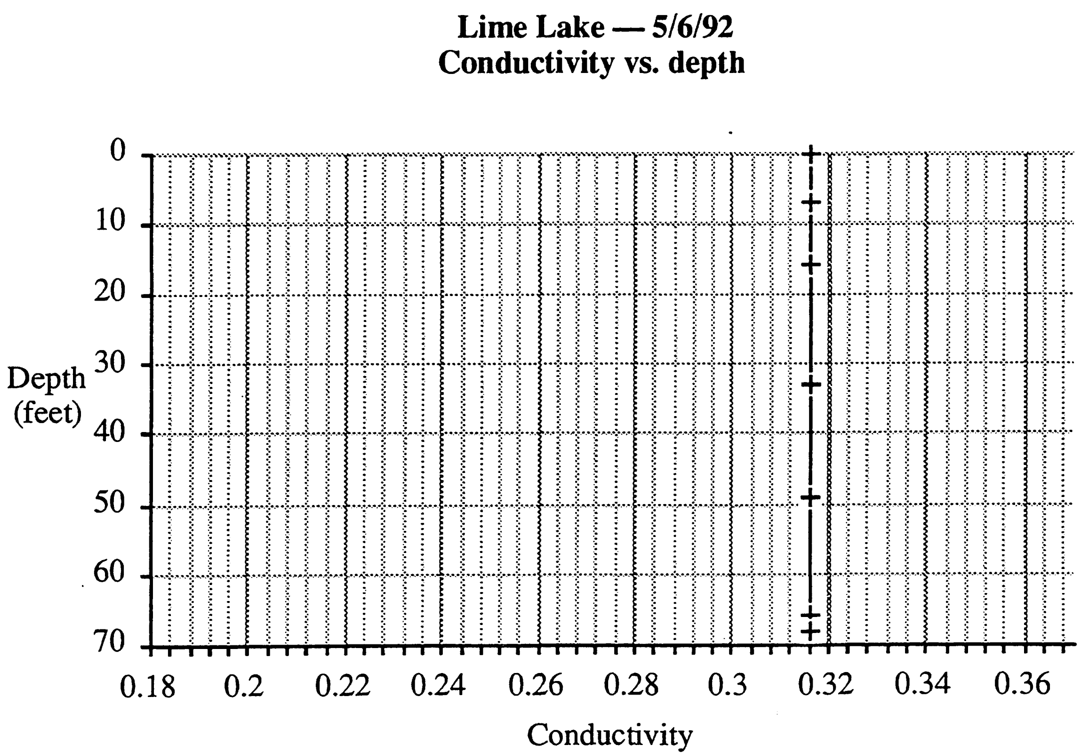


Figure 36h: Lime Lake conductivity measurements.

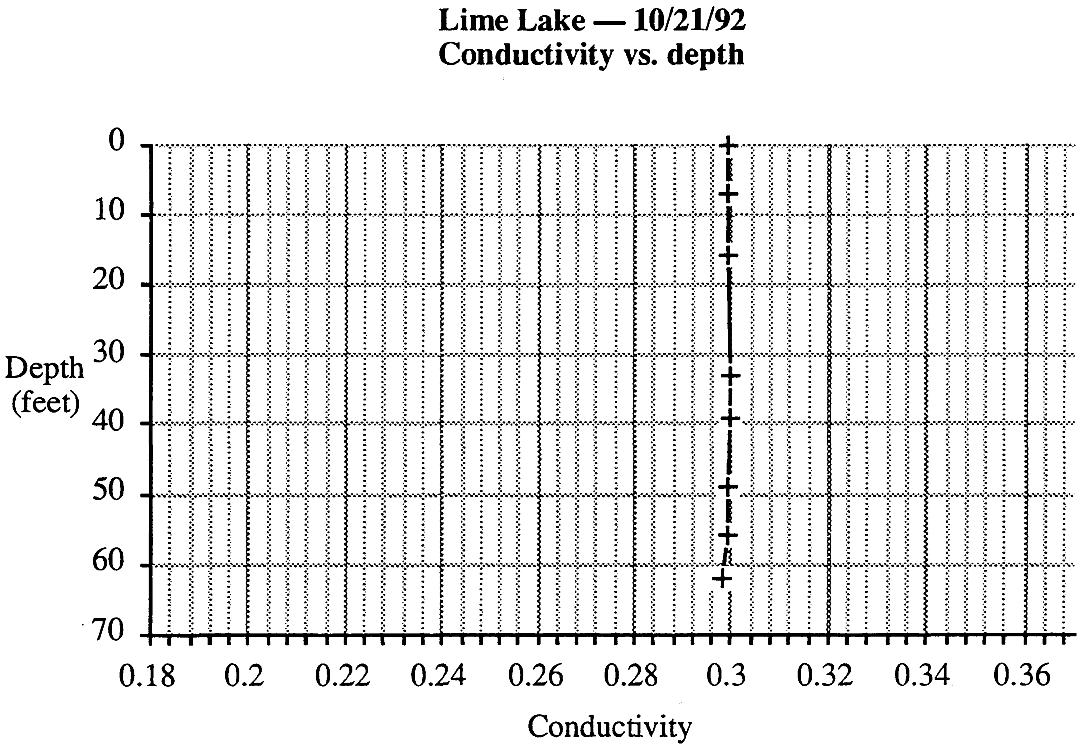


Figure 36i: Lime Lake conductivity measurements.

In general, the conductivity measurements in Little Traverse Lake were slightly higher than those of Lime Lake, as shown in Figures 37a through 37h. In 1990 the epilimnion conductivity ranged from .29 to .33. The highest value of .33 occurred on June 25 when there may have been more recreational and boating activity on the lakes. The conductivity for 1991 was relatively low during the beginning of the year ranging from .29 to .31 at the highest. On September 11 the conductivity dramatically rose to .34 in the epilimnion for no apparent reason. It remained near this level through the fall overturn and into the next year. In 1992 the conductivity was generally higher and more erratic. The lowest measurement was .245, which seemed out of context with the rest of the measurements. The highest surface measurement was .34 on June 24 which correlates well to the 1990 data for the highest measurements. In general the values seemed to be at .33 throughout most of the year, which is higher than the previous years.

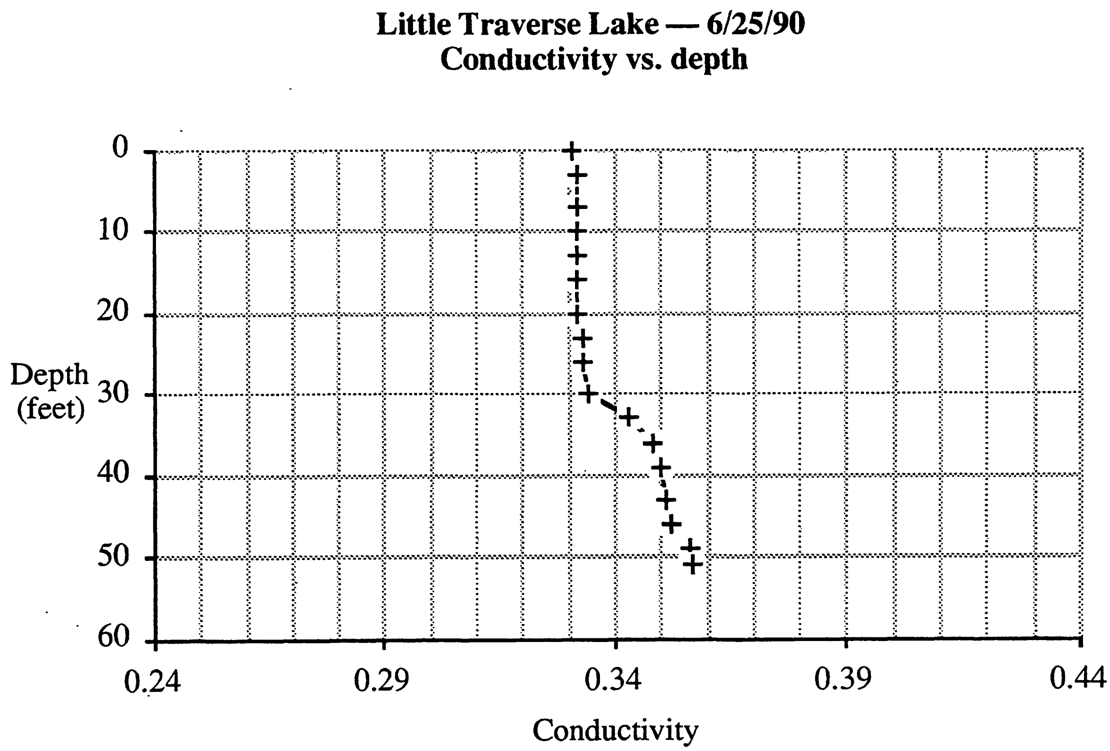


Figure 37a: Little Traverse Lake conductivity measurements.

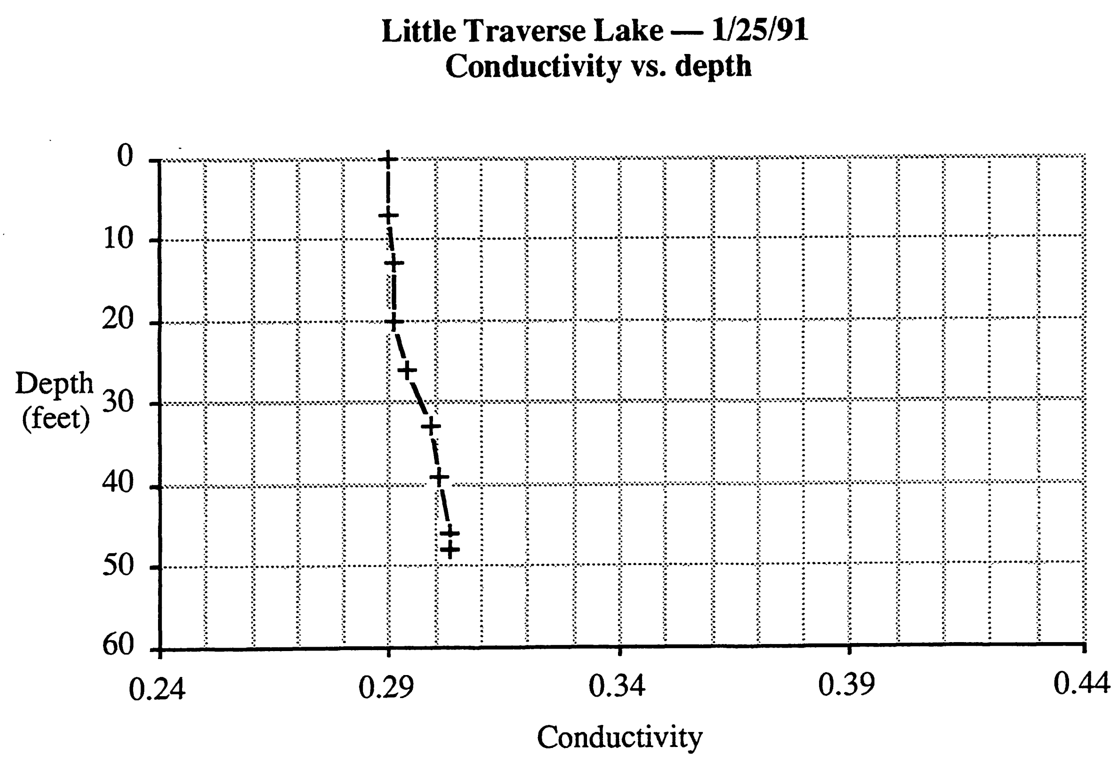


Figure 37b: Little Traverse Lake conductivity measurements.

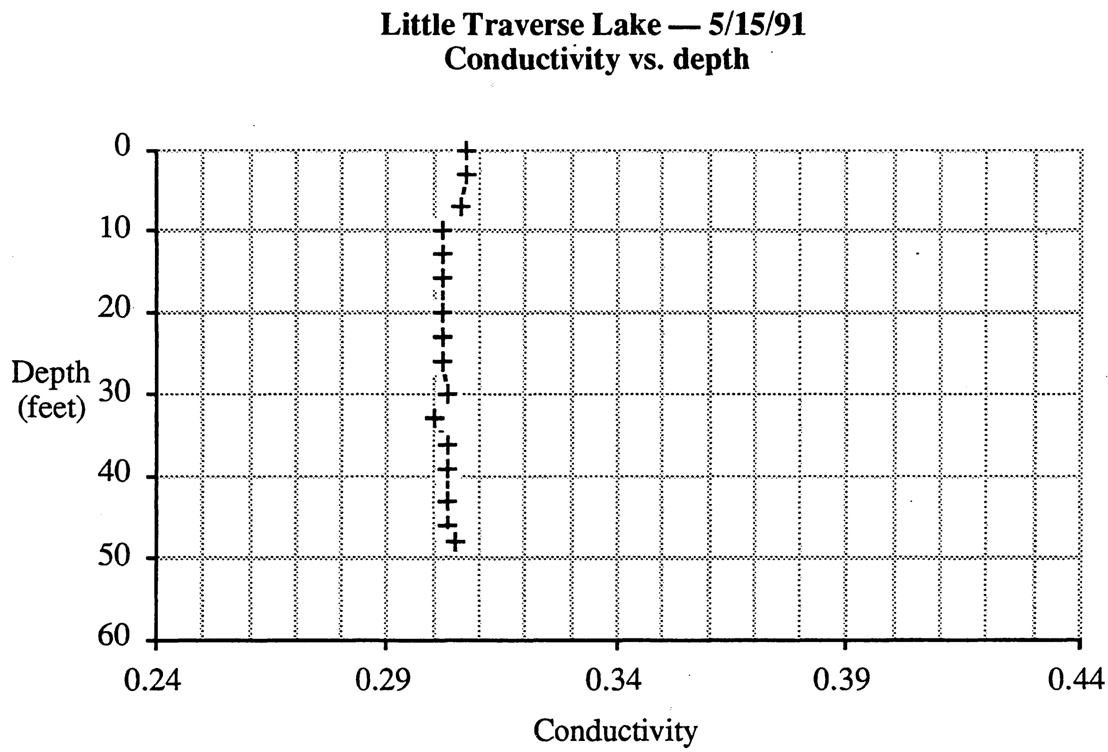


Figure 37c: Little Traverse Lake conductivity measurements.

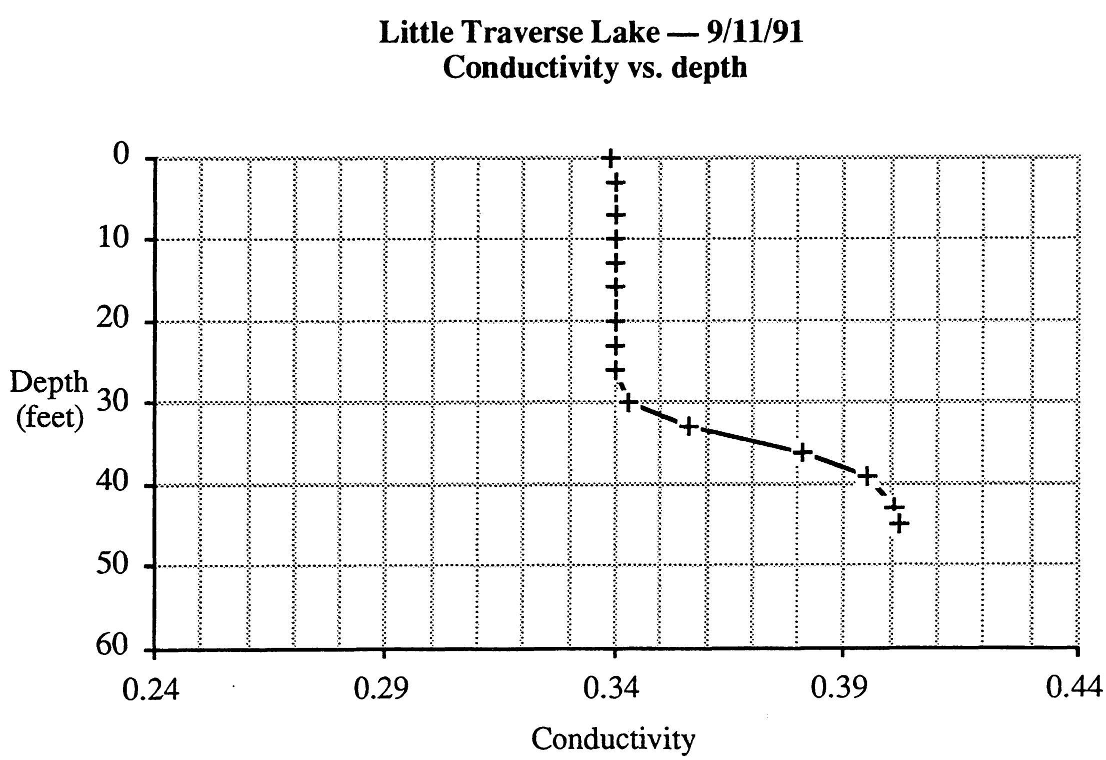


Figure 37d: Little Traverse Lake conductivity measurements.

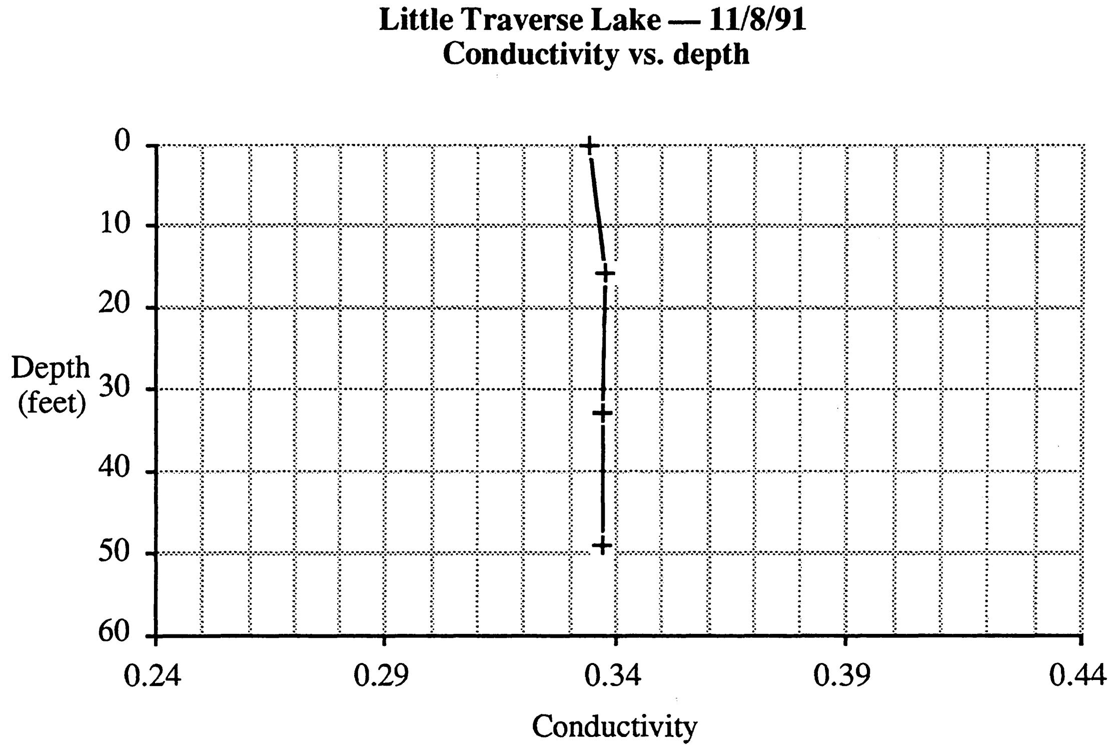


Figure 37e: Little Traverse Lake conductivity measurements.

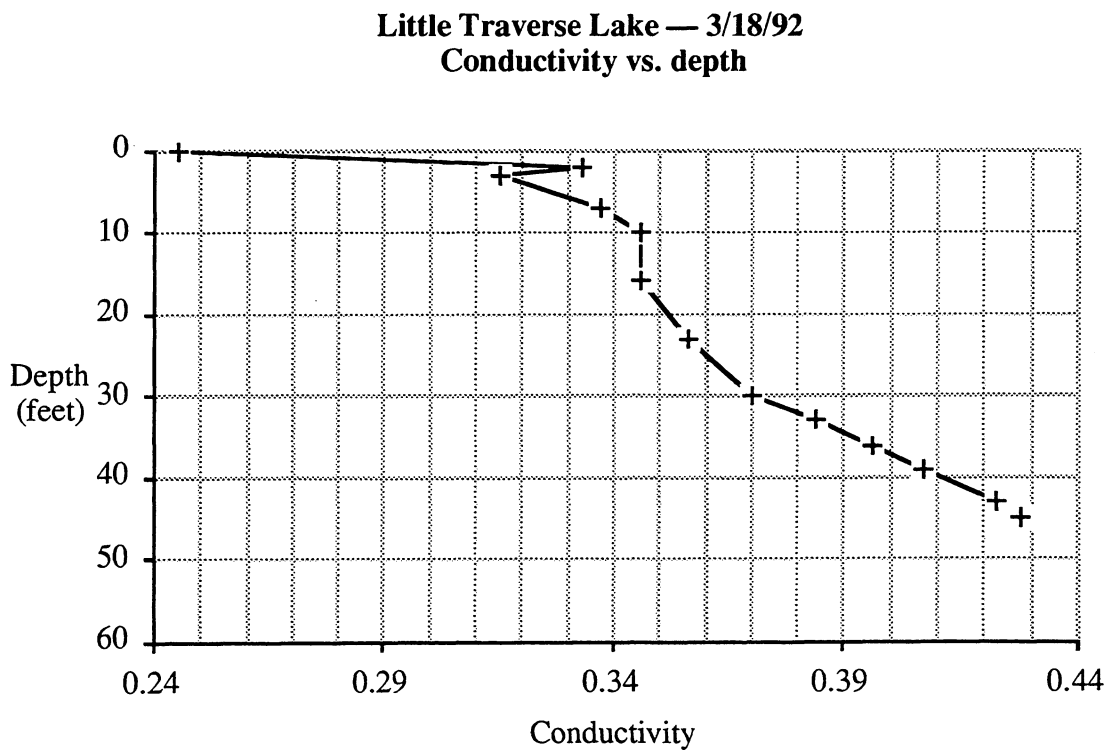


Figure 37f: Little Traverse Lake conductivity measurements.

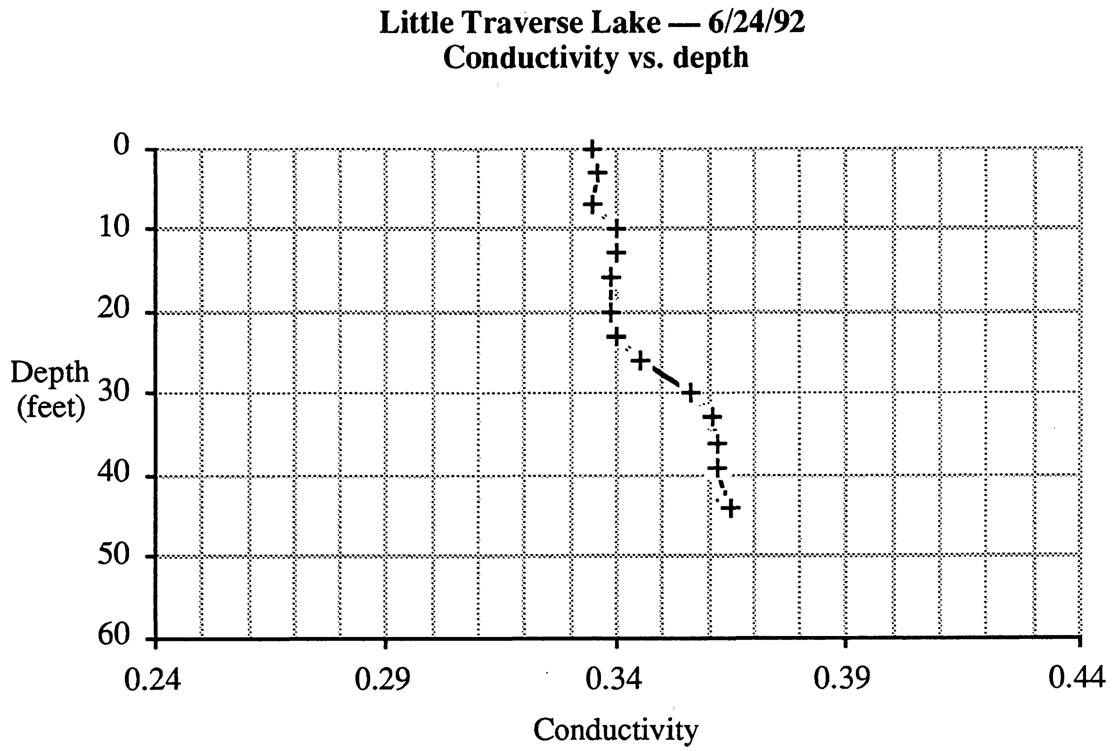


Figure 37g: Little Traverse Lake conductivity measurements.

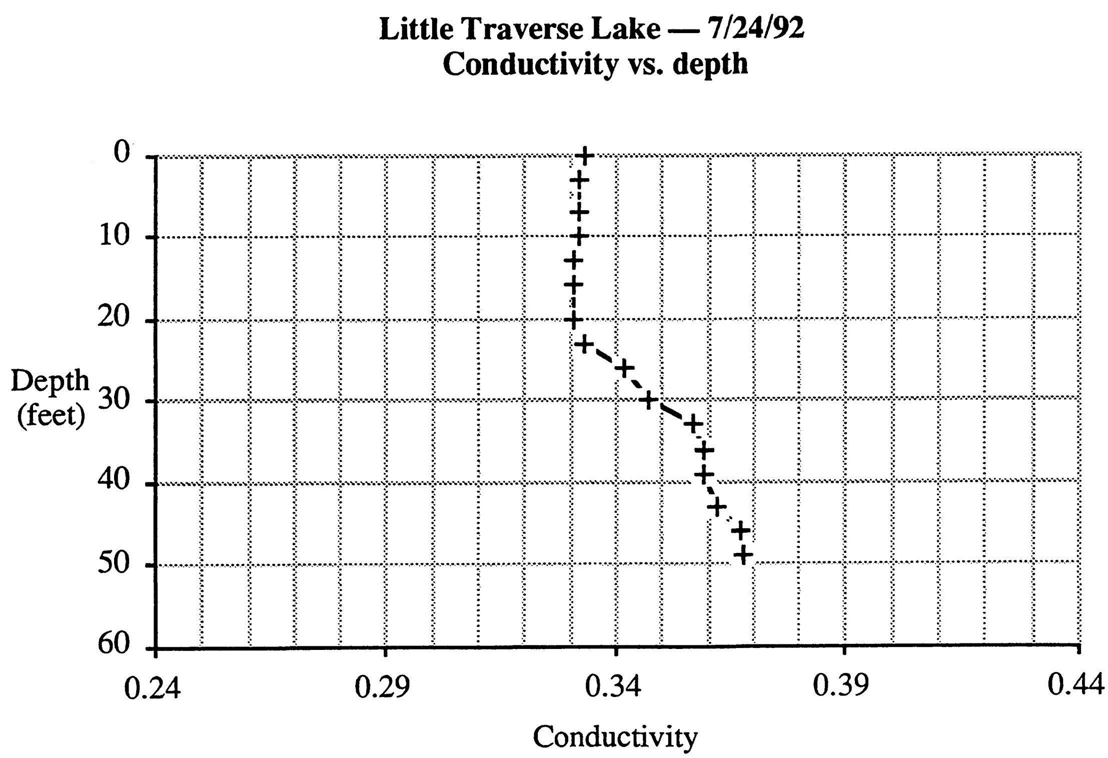


Figure 37h: Little Traverse Lake conductivity measurements.

The data from the three years would seem to indicate that the conductivity has been slowly rising each year. More substances may be entering the lakes as time goes on, whether from increased nutrients, increased construction on the lakes or inlet streams feeding the lakes, or decreased vegetation bordering the lakes (see buffer strips). Three years is not enough data to allow valid conclusion of a trend.

j. Carbon Dioxide

This test has seldom been done in either Lime or Little Traverse Lake. Carbon dioxide (CO_2) is a requirement for photosynthesis, and is a by-product of respiration of plants and animals. Often CO_2 accumulates in the hypolimnion, displacing DO and lowering the pH.[69]

Lime Lake was tested twice for CO_2, on August 7, 1947 and August 30, 1949. Phenolphthalein and methyl orange are tests normally used to determine alkalinity, but can also be used to determine the amounts of CO_2. The phenolphthalein tests seem to indicate that there is some CO_2 at the surface and none in the hypolimnion, while the methyl orange tests indicate that there is a good amount in the epilimnion and a slight accumulation near the bottom. Due to the pH results, it is not expected that the CO_2 levels would be high.

Little Traverse was tested once on August 30, 1949 showing similar results.

k. Hardness

This is the measure of multivalent metallic cations in solution, usually calcium (Ca) and magnesium (Mg). Table 12 categorizes lakes as to the amounts of Ca and Mg in mg/l in solution.

Table 12: Hardness of water.[23]

< 50 mg/l	soft
50 to 150 mg/l	moderately hard
150 to 300 mg/l	hard
>300 mg/l	very hard

Lime Lake was tested by the MDNR on August 6, 1973 for this measure. The average at the two depths taken was 179.55 mg/l, which would indicate that it is a hard-water lake.

l. Oxidation Reduction Potential

During the summer months, many elements such as phosphorus and iron become tied up with elements such as oxygen. These compounds are heavier than the water and consequently settle into the bottom sediments. During the summer stagnation period, oxygen is often depleted in the hypolimnion, as discussed under stratification heading. Under such conditions, these phosphorus and iron compounds as well as sulfur, nitrogen, carbon, and many metallic elements are reduced to forms which can easily go into solution. Oxidation Reduction Potential (ORP) is a test which measures the amount of ions which go into solution under such conditions.[2]

The term oxidation refers to the combination of oxygen to an element, or the loss of electrons from such element. Reduction is the opposite of this, hence, the loss of oxygen from a compound or the gaining of electrons. One example of this is rust in the equation: $4Fe + 3O_2 = Fe_2O_3$ In this equation the iron was oxidized from Fe to Fe^{3+}, while the oxygen was reduced from O to $O^{=}$.[23]

Iron and phosphorus go into solution at a measurement of 0.2 volts; $SO_4^{=}$ (sulphate) becomes $SO_4^{=}$ (hydrogen sulfide); and elemental sulfur at 0.1 to 0 volts.[53] The symbol + signifies oxidation and - signifies reduction. Values are multiplied by 1000 and 200 is then added to convert these values to mV.[30]

The data from the conservancy shows that in 1990, neither lake fell into negative numbers, but in 1991 and 1992, both lakes did fall below zero. This does not correlate with the DO values which in 1991 were higher than the other two years. Lime Lake 1992 shows the most dramatic changes in ORP, which can be seen in Figures 38a through 38f.

Lime Lake — 2/28/92
Oxidation reduction potential vs. depth

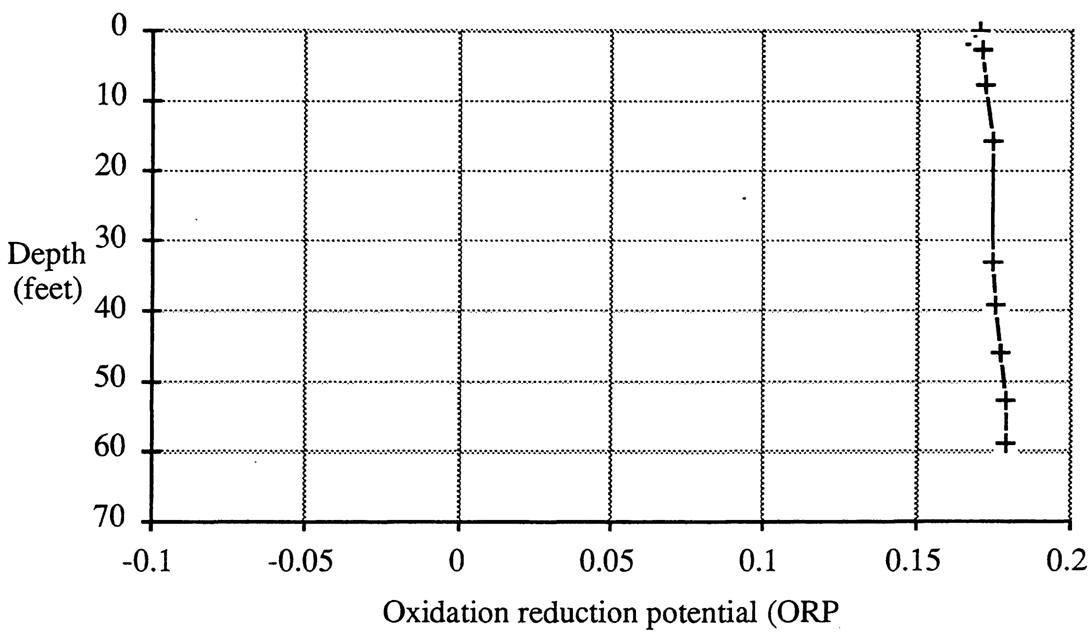


Figure 38a: Lime Lake oxidation reduction potential measurements.

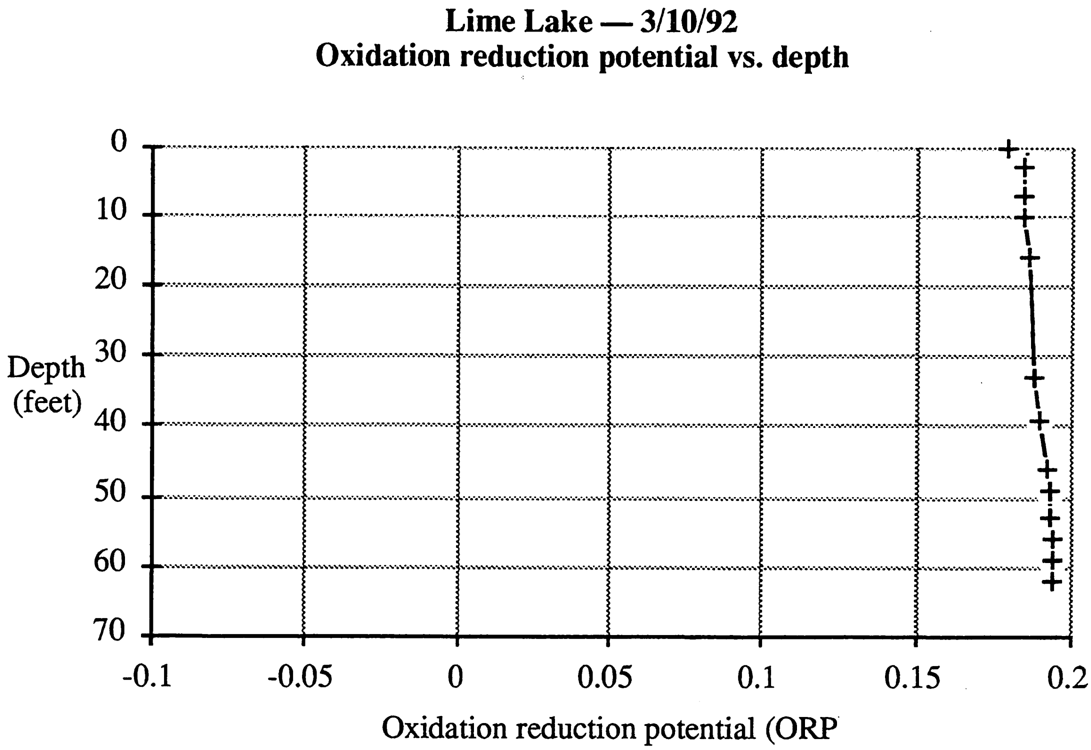


Figure 38b: Lime Lake oxidation reduction potential measurements.

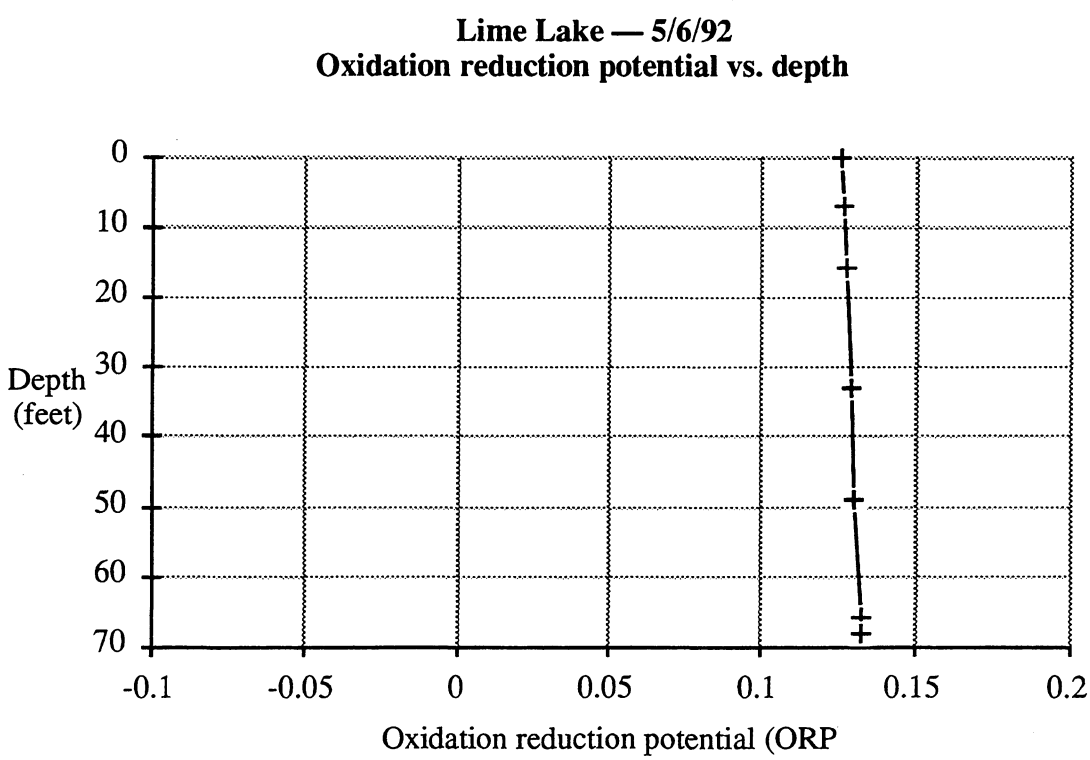


Figure 38c: Lime Lake oxidation reduction potential measurements.

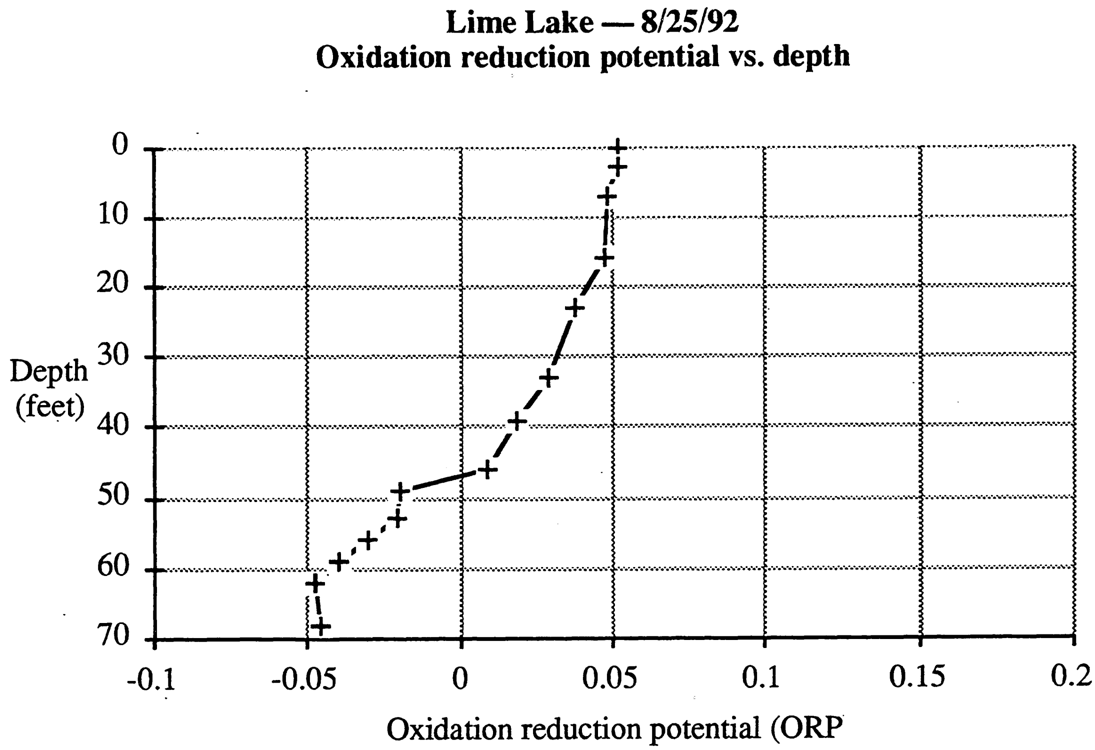


Figure 38d: Lime Lake oxidation reduction potential measurements.

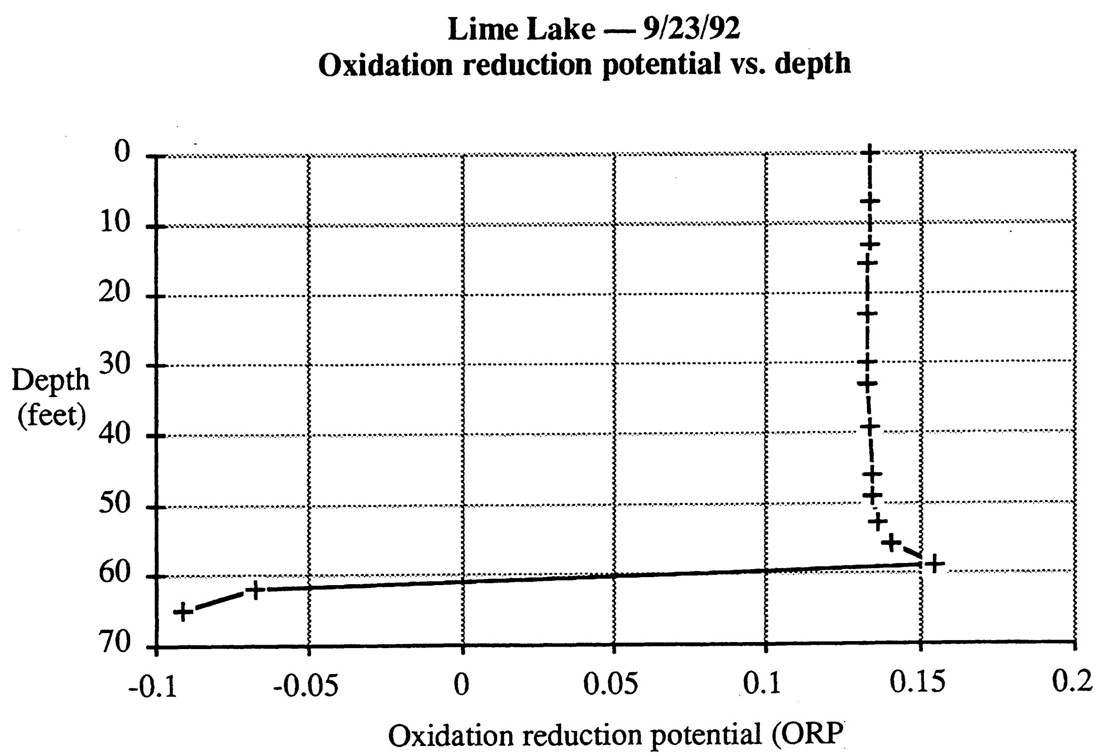


Figure 38e: Lime Lake oxidation reduction potential measurements.

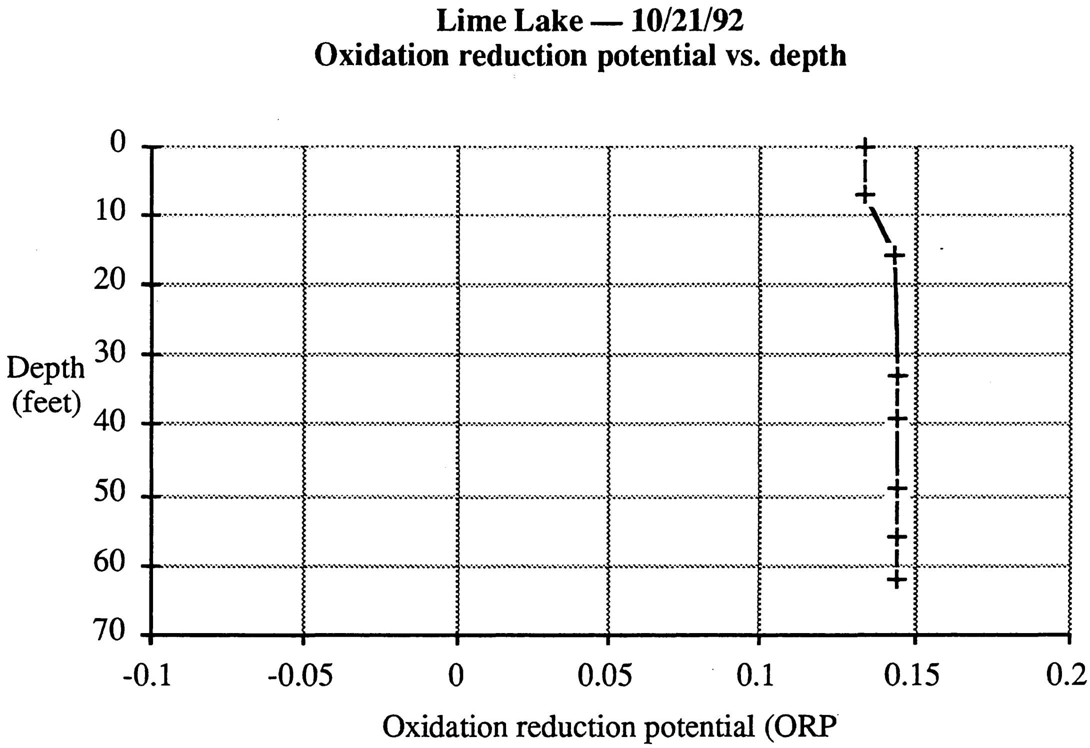


Figure 38f: Lime Lake oxidation reduction potential measurements.

On February 28 1992 the ORP values in Lime Lake were relatively high at ±0.175. ORP rose slightly March 10, but dropped by May 6 down to 0.125. It remained close to this range until August 25 when the surface dropped to 0.05 and the lake bottom went down to -0.05. On September 23 the surface values rose to 0.18 while the bottom fell to -0.1. After fall overturn was complete, the ORP was uniform throughout the water column.

There does not seem to be a correlation between the low ORP values and total phosphorus levels after the fall overturn as one would expect. This may be due to higher inputs of phosphorus into the lake during mid summer, than there are in the sediments that go into solution.

m. Alkalinity

Alkalinity is a measure of the buffering capacity of the water to neutralize acids (absorb H^+ ions), without changing the pH.[23] The most numerous of such buffering agents include carbonate ($CO_3^=$), bicarbonate (HCO_3^-,) and hydroxide (OH^-), with others such as borates, phosphates, and silicates.[3]

Tests used in the past for alkalinity were phenophthalien and methyl orange. The phenolphthalein test measures the amount of, hydroxyls, carbonates and bicarbonates above a pH of 8.3. Methyl orange measures the rest of the buffering agents to a pH of near 4.5. Total alkalinity can be figured from these two measurements.[23,70] Alkalinity is not currently being tested by the Leelanau Conservancy, but has been tested in the past. The results of the past testing can be seen in Table 13. Data which was collected at different depths were averaged.

Table 13; Averaged information from data taken by the Institute For Fisheries Research and the MDNR.

Date	Little Traverse Lake	Lime Lake
8/30/49	147	
9/9/70	113	
8/6/73		171
5/2/78		154
8/1/78	182.4	
8/26/80		146.3
7/16/85		141

Based on parameters for alkalinity given in Table 5 of the section Measures to Determine Water Quality, it would seem that the buffering capacity in Lime and Little Traverse Lakes is good for the life of most aquatic organisms.

n. Turbidity

Turbidity is determined by the amount of light that is scattered and absorbed in water, as opposed to transmitting throughout the water column, as far as the wavelengths would in distilled water without interference. Such interference is caused by matter in solution, primarily; clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and microscopic organisms suspended in the water column.[2] The standard tests for turbidity are measured in Jackson Turbidity Units JTU, or Nephelometric Turbidity Units NTU.[2] Lakes under 25 JTU's are considered clear, while over 100 JTU's are considered muddy.[23]

The only test ever taken on either lake was on August 26, 1980 for Lime Lake. The test was taken using equipment from Hach, which is a supplier of water quality equipment. The measurements were given in FTU's, which are units sometimes replacing NTU's when Formazin polymer is used.[23] The average of the three depths taken was 1.4, which seems to be much lower than one would expect in a marl lake.

o. Coliform Bacteria

Coliform is a type of bacteria found in human and animal wastes. Coliform is harmless to humans, but is found in association with many other disease causing bacteria and viruses. For this reason, it is used in Michigan and by the EPA as an indicator of the safe levels of other bacteria in the water. Refer to Table 4 for the standards for drinking water and recreational activities.

Bacteria enters the water through inefficient septic systems, storm sewers, and animal waste including pets and livestock allowed close to or in the water.

Neither lake has been tested for any bacteria. Testing around the edges of the lake may locate faulty septic systems. It is doubtful that the coliform levels are too high for recreation, but tests taken near the shore may indicate where faulty septic systems are occurring.

p. Pesticides

Testing for pesticides is important because these chemicals may enter a body dermally while swimming, or may enter the human body orally by drinking the lake water or eating fish or waterfowl which have accumulated these chemicals into their fat or flesh.[42]

There have been many pesticides used in and around both lakes historically. Agriculture was probably the first pesticide use. Homeowners now also use herbicides, insecticides, and fungicides for lawn and garden applications. The Institute for Fisheries Research also has records of the use of poisons in Lime Lake to kill yellow perch on August 6, 1959. The pesticide Toxaphene was added to the epilimnion of Lime Lake in concentrations of 2.3 parts per billion. The objective was to benefit the stocked trout population. Perch kill was light.[26]

Pesticides need not be applied near or in the lakes for them to be found in the water. Pesticides can enter a lake through wind-blown sediments, streams, runoff, and from the atmosphere. Cherry orchards are a major agricultural activity within the watershed, involving potential risk of pesticide contamination.

Orchards and other specialty crops which use a combination of pesticides have a high probability of surface runoff. The most common types of pesticides used in orchards are insecticides, fungicides, and miticides, many of which are toxic to aquatic invertebrates and fish. These chemicals are generally rated as having a small-risk potential for leaching, but a high risk for runoff. Most of the foliar applications are broken down by sunlight, but rainfall after an application will increase the chances of runoff.[37]

Potential problems stem from storage of chemicals and pesticides in tanks; equipment filling locations; application processes; and disposal of the rinsate from rinsed crops. After tart cherries are harvested they are cooled down by water in cherry cooling pads. Two concerns with this practice are 1) soil erosion from water leaving the site and 2) possible water contamination by pesticides from the cherries being washed.

Water and wind erosion of farmland soil carries the highest amount of pesticides and nutrients. A major study on Houdek Creek Watershed estimates that 13,000 tons of soil is eroded annually from cropland within that watershed. GIS data has shown that 5,400 tons of soil are eroded from within a quarter of a mile of the stream, and approximately half of that actually reaches the stream.[37]

Public Health fish consumption advisories remain in place for many Michigan waters because the tissues of various fish species are contaminated with elevated levels of toxic materials. These are acquired from the water itself and from bioaccumulation from ingested prey organisms. It is suspected that much of the material comes from three types of sources — atmospheric deposition, point source charges, and the presence of contaminated bottom sediments.[41]

Pesticides are of concern for three reasons. 1) Consumption of contaminated fish can be a major route of human exposure to toxic substances. Certain substances, while not lethal to fish, have bioaccumulated in tissues of some Michigan fish species to levels unacceptable for human consumption.[47] Some examples are polychlorinated biphenyl's (PCBs) and 2,3,7,8 Tetrachlorodibenzo-p-dioxin (dioxin). 2) Toxic substances at elevated levels in fish indicate water quality problems. 3) High toxic levels in fish may reduce growth rates, reproductive success, and survival of fish populations.[41]

Michigan expanded water quality standards in 1985 to assure that not only is the water non-toxic, but also that fish are fit for human consumption. The risk assessment process, and the upper limit on risk for chemicals assumed to be non-threshold carcinogens, were major issues deliberated during Rule 57 development. The resulting rule requires that a point source discharge not create an estimated level of increased cancer risk greater than 1 in 100,000 above the background in the surface water after mixing with the allowable receiving stream volume specified in the mixing zone rule and calculated using the model and assumptions specified in the Rule 57 Guidelines.[41]

q. Salts

Road salts and other de-icing chemicals pose threats to groundwater when heavy use occurs in areas with sandy soils or high water tables. The Michigan DNR reports that there has been a general statewide increase in the sodium concentration of groundwater, but the contribution of road salt to this problem is unclear.[42]

r. Aquatic Macrophytes

The macrophyte community on both lakes were too sparse to cause problems with any types of recreation, and seemed to be consistent with the types of vegetation found in oligotrophic lakes of the area.

The project group created a computer database of macrophytes, including aquatic and emergent plants, and attached algae which could be found in a vegetative buffer zone along the riparian edge. Included are plants the group believes to have found in Little Traverse and Lime Lakes .This database was supplied to the Leelanau Conservancy.

A sample of the aquatic database is included in Appendix C.

s. Fish and the Food Web

A list of fish species and other aquatic organisms was compiled for Lime and Little Traverse Lakes from records of the Institute for Fisheries Research as well as the Summer 1993 survey sent to the residents of each lake. The data as it relates to the food web can be seen in Table 14. Also shown is the organism's trophic level In the food web and their primary habitat(s) within the lake zones. The trophic levels each organism is determined to be is listed in the third column. The zone which each organism is listed in the last column along with the seasons in which it can be found there. The abbreviations are as follows: sp = spring; su = summer; f = fall; and w = winter.

Table 14: Types of aquatic organisms recorded as captured, observed, or stocked in Little Traverse and/or Lime Lakes.[4,5,6,7,8,26,48,52,54,60,64]

Organisms Found In the Lakes	Scientific Name	Trophic Level (s)	Habitat (s)
PIKE FAMILY	ESOCIDAE		
Northern Pike	*Esox lucius*	3,4,5	Littoral= sp, f : profundal= su
SUNFISH FAMILY	CENTRARCHIDAE		
Smallmouth Bass	*Micropterus dolomieui*	3,4,5	Littoral= sp : profundal= su
Bluegills	*Lepomis macrochirus*	2,3,4	Littoral= sp, su, f : profundal= w
Pumpkinseed	*Lepomis gibbosis*	3	Littoral
Largemouth Bass	*Micropterus salmoides*	3,4,5	Littoral= sp, su, f
Rock Bass	*Ambloplites rupestris*	3,4	Littoral to pelagic
Black Crappie	*Poxomis nigromaculatus*	3,4	Littoral
PERCH FAMILY	PERCIDAE		
Yellow Perch	*Perca flavescens*	3,4	Littoral/pelagic= diurnal and seasonal movements
Pikeperch, Walleye	*Stizostedion vitreum*	3,4	Littoral
Logperch	*Percina caprodes*	3	Littoral/profundal
SALMON FAMILY	SALMONIDAE		
Brook Trout	*Salvelinus fontinalis*	3,4	Littoral/streams
Herring, Ciscoes	*Coregonus artedi*	2,3	Pelagic= sp, f : profundal= su
Lake Trout	*Salvelinus namaycush*	3,4	Littoral= f : pelagic= sp : profundal= su
Rainbow Trout	*Salmo gairdneri*	3	Littoral/profundal/ streams
Brown Trout	*Salmo trutta*	3,4	Littoral/streams
SUCKER FAMILY	CATOSTOMIDAE		
White Sucker	*Catostomus commersoni*	3	Littoral/pelagic
CATFISH FAMILY	ICTALURIDAE		
Black Bullhead	*Ictalurus melas*	2,3	Littoral
Brown Bullhead	*Ictalurus nebulosus*	2,3	Littoral
HERRING FAMILY	CLUPIDAE		
Alewife	*Alosa pseudoharengus*	3	Littoral= sp : pelagic= night : profundal= day
MINNOW FAMILY	CYPRINIDAE		
Spottail Shiner	*Netropis hudsonius*	2,3	Littoral
Bluntnose Minnows	*Pimphales notatus*	2,3	Littoral
Blacknose Dace	*Rhinicthys atratulus*	2,3	Littoral/streams
MAMMALS			
Beaver	*Castor canadensis*	2	Littoral
Star-nosed Mole	*Condylura cristata*	2	Terrestrial
Mink	*Mustela vison*	3,4	Littoral/terrestrial
Raccoon	*Procyon lotor*	2,3	Terrestrial
White-tailed Deer	*Odocoileus virginiana*	2	Terrestrial
DUCKS			
MERGANSERS			
Common Merganser	*Mergus merganser*	3,4,5	Littoral/pelagic
Hooded Merganser	*Lophodytes cucullatus*	3,4,5	Littoral/pelagic
DABBLING DUCKS			
Mallards	*Anas platyrhnchos*	2	Littoral
SWANS (Subfamily)	CYGNINAE		
Mute Swans	*Cygnus olor*	2	Littoral
HERPTILES (Class)	AMPHIBIA / REPTILA		
Snapping Turtles	*Chelydra serpentina*	1,2,3	Littoral
Painted Turtles	*Chryemys picta*	1,2,3	Littoral
CRUSTACEANS (Class)	CRUSTACEA		
Crayfish (Order)	DECAPODA	2,3	Littoral
(Phylum)	ANNELIDA		
Leeches (Class)	HIRUDINEA	3	
SPONGES (Phylum)	PORIFERA		

(Order)	MONAXINIDA		
Freshwater Sponge		3	Littoral
INSECTS (Class)	INSECTA		
(Order)	ODONATA		
(Suborder)	ANISOPTERA		
Dragonfly Larvae		3	Littoral
(Order)	EPHEMEROPTERA		
Mayfly Larvae		2	Littoral
Mayfly Hatch		2	Air/terrestrial
Junebugs	*Phyllophaga spp.*	2	Terrestrial
PLANT (Kingdom)	PLANTAE		
Muskgrass	*Chara spp.*	1	Littoral
Pondweed	*Potamogeton spp.*	1	Littoral
Bulrush	*Scirpus spp.*	1	Littoral
Water Milfoil	*Myriophyllum spp.*	1	Littoral
Elodea	*Elodea spp.*	1	Littoral

Some respondents to the 1993 survey indicate a perceived decline in populations of some fish species in the lakes. Rainbow trout were stocked in 1987. Brown trout were stocked by the MDNR until 1990. Based upon testing from the summer of 1949, there is not enough DO in the hypolimnion to support trout in mid-summer, as indicated in a letter on February 17, 1953 by C.M. Taube, an Assistant Fisheries Biologist from the Institute for Fisheries Research.[26] Bluegills have also reportedly declined. Possible causes may be a declining macrophyte population, or parasites which are blinding the bluegill. So far there has been little bluegill stocking by the MDNR, with the exception of 207 in 1991. There has been a reported decline in the population of bluegills in this lake from members talked to from the lake association, and as reported from the survey results. Speculation is from a declining weed population and from a parasite which blinds the fish.

2. Conclusions

More chlorophyll *a* testing would allow comparison of chlorophyll *a* with total phosphorus and secchi disc, which would help to rate trophic status of the lakes.

The most useful tests for these lakes are temperature, dissolved oxygen, total phosphorus, nitrogen (total nitrate and nitrite, ammonia, and kjedahl), chlorophyll *a*, alkalinity, pH, and conductivity.

The grading system developed by Fusilier and Fusilier is a good model to use, but the Leelanau Conservancy unfortunately does not have all of the testing equipment necessary for these tests. This model contains many parameters which could be very important to the users of the lakes. This model should be given further consideration in the future.

The Leelanau Conservancy has begun to build a nutrient budget for the two lakes. This is still in its infancy and it take years to produce conclusive results.

Other parameters which should be tested on a one time basis are fecal coliform, Toxephene and other pesticides, and lead and mercury. It is important to know if these are currently polluting the lakes. Fecal coliform should be tested periodically, while the other parameters may only need to be tested for once.

It may be helpful for future years to do an in-depth study of the flora and fauna of the Lime and Little Traverse Lakes to determine if these organisms are consistent with those of a hard-water, oligotrophic lake. These findings could also be helpful if other in depth studies are carried out in the future at twenty year intervals.

III. The Stewardship Ethic

Riparian homeowners can act both individually and as part of a lake association to preserve the health and beauty of their lake and surrounding landscape, while also protecting their property investment.

A. Individual Stewardship

Lakefront property owners should be especially aware and concerned about simple household activities and decisions that can influence lake and ground water quality. Water from household drains and appliances carries solids, greases, cleaning agents and chemicals, and effluent that pass through the septic system into the groundwater. Residential landscape vegetation and type of fertilization can affect water quality through erosion, sedimentation, and nutrient pollution. Visual aesthetics and views from on or across the lake are also influenced by landscaping, erosion, man-made shoreline stabilization, and built structures, all of which should be harmonious with the natural landscape and neighboring homes.

Homeowners' activities produce small incremental effects that may be cumulative over a longer period of time. Collectively these negative effects may take decades to become obvious. Lake monitoring allows for early detection of deteriorating quality, and for immediate corrective measures to be taken before impacts become difficult or impossible to reverse.

Homeowners should be aware of practices known to degrade visual and environmental quality in the watershed beyond their own personal property. Short-sighted land use planning, lax zoning regulation, and careless construction practices can permanently alter the natural character of the region. The most obvious preventative measure is to restrict development along the lakes or within the watershed. This is neither politically viable nor publicly desirable. More reasonable measures include restricting development to suitable sites, using responsible development practices, and correcting the adverse results of previous practices. Awareness and concern by existing homeowners can begin by studying how their own property maintenance and activities impact the lakes.

Beyond awareness and concern, there should be consensus and commitment among homeowners to protect lake quality by collective action. Homeowners may be motivated to work toward the long term environmental benefits of maintaining lake quality as a means to protect recreational suitability for swimming, boating, and fishing, to preserve scenic beauty for future generations, and to protect the monetary value of their property. Although many residents are seasonal, they may view their vacation property as a future year-round retirement home, and so have a vested interest in preserving the quality of the region.[21] In general, homeowners need only reflect upon the reasons they originally bought their property.

The economy of the region depends heavily upon tourism. Nearly all business in the county is dependent to some degree upon tourist spending. Preservation of the scenic beauty and recreational opportunities of the lakes is critical in sustaining tourist trade and bolstering the local economy.

B. Role of Lake Associations In Stewardship

Lake associations can play several important roles in maintaining lake quality and aesthetics. These include education, policing, lobbying, and monitoring.

Local lake associations provide a valuable educational forum for discussing lake-related issues, dispersing information, studying the merits of various courses of action, and building consensus for taking collective group action.

The lake association can act as an informal policing body, representing the lakefront community as a whole in a complaint against an individual property owner. It is more difficult for an individual to ignore the association's combined peer pressure than it would be to ignore isolated complaints. This can also reduce the level of personality involvement and conflict.

The lake association can lobby public agencies with community viewpoints and complaints. Zoning regulations and guidelines are often under pressure by developers who want increased density, or access to a lake for residents of a future development by means of a single "keyhole" lakefront lot (discussed further in later section Inland Lake Development-Local concerns). The lake association can apply political pressure more effectively than could individual residents.

Lake water quality monitoring can be organized and conducted by a lake association. Remedial efforts have greater results when done as a coordinated effort. Involvement of the community as a group leads to environmental education, sense of civic responsibility, cooperation, and pride.[21]

Those who join a lake association must be willing to give up some individual rights and possibly incur some costs for the overall good of the lake environment. They must convince others to join. There are conflicting interests of personal cost/benefit versus collective community and environmental cost/benefit. Not everyone will join a lake association, betting that everyone else will make the effort. Whatever happens to the lake affects everybody, so the non-joiner can benefit from any improvements. For example, if association members decide to have their septic systems pumped and inspected, the non-member may save money and still benefit from the water quality improvement— this assumes the non-member agrees with the associations goals and objectives of clean water. On the other hand, if they are at odds with association policy, non-membership does not allow them to voice a viewpoint for or against. Such association policy could include types of lawn fertilization, shoreline erosion, dock length, water level, fish stocking, or number and types of boats. For seasonal residents, the lake association may be their only opportunity for a voice in local government.[21]

IV. Homeowner Responsibilities & Practices

Homeowners have the responsibility to avoid practices that have adverse effects on lake water quality. Non-point pollution is the leading cause of water quality degradation in northern Michigan lakes .[62] This type of pollution comes from many diffuse sources and enters water bodies at undefined locations. Point sources of pollution originate at a known source and enter the water at a specific location. Examples of non-point pollution are runoff from agricultural and residential properties, septic tank leakage, and acid rain. Development pressure adjacent to lakes increases the potential for non-point pollution due to use of septic system, fertilizers, pesticides, and household chemicals in close proximity to the ground and surface waters.[37]

Based on responses to our surveys, the lowest occupancy rate is in February when 52% of homes on Little Traverse and Lime Lakes are occupied with 2.3 persons per occupied household. The maximum occupancy of approximately 95% occurs in July and August with about 3.5 persons per occupied household. Demands of heavy water use and organic loading upon the septic system, as well as lawn fertilization would be highest in mid-summer. The majority of homes responding to the 1993 Survey on both lakes reported owning washing machines (77% to 85%), while at least half own dishwashers. These types of appliances can also contribute to non-point pollution by phosphorus. This correlates with the water quality phosphorus testing that shows highest levels in mid-summer.

A. Dealing with Household Waste

Household wastes can pose a serious problem to lake water quality. Some of these wastes that are indiscriminately put down drain enter the groundwater which feeds the lakes. Most of the households around Lime and Little Traverse Lakes have septic systems. It is important for the homeowner to know how they work and how they effect lake quality.

In the 1993 Survey the majority of respondents reported their septic field to comply with current Health Department regulations for setback distance away from the lakeshore. The majority of systems are 10 to 25 years old, and while most are pumped within every 5 years, a significant minority of as many as 15% are pumped less frequently or do not know when. Overall, septic systems have not been reported to be a serious problem at this time. Literature suggests that survey return is less likely if a property owner suspects a problem to exist.[62] Some may not want to divulge information if they are not certain of confidentiality.

1. Septic Systems

All of the residences surrounding Little Traverse and Lime lakes use septic system of varied configurations to dispose of household effluent. There are no municipal sewage systems around these lakes because they are not economically or politically viable.

a. How They Function

Septic systems consist of a settling tank and a drain field. Waste is collected in the settling tank where solids settle to the bottom as sludge. The scum which floats to the surface of the liquid is primarily grease and fat. The waste in the tank is partially decomposed by anaerobic bacteria which function in the absence of oxygen. Many of the acid by-products of anaerobic decomposition such as methane, ammonia, and hydrogen sulfide are toxic to most plants.[67] Scum and sludge are retained in the tank by placement of baffles at the top and bottom of the tank. After approximately 24 hours, relatively clear liquid moves into the drain field. The drain field consists of a parallel pattern of buried perforated pipes or tiles that distribute liquid effluent throughout the upper soil layers.[37] In the soil, organic compounds in the effluents are further broken down in a process of aerobic digestion by bacteria in the soil. This process requires the presence of oxygen, and the end products are compounds usable by most higher plants. The soil particles also act as a filtration system. Suitable soils have the ability to absorb phosphates and many non-organic chemicals before they can reach groundwater. When the water reaches the water Table it should be drinkable. Septic fields should be at least 100 feet from wells.[66] Design and siting guidelines for small scale residential septic systems are set by the Leelanau County Health Department. Larger housing developments are regulated by the State Public Health Department.[21]

Periodic maintenance entails pumping the tank; otherwise an extreme buildup of sludge and scum will allow un-decomposed effluent to enter the drain field. This interferes with the aerobic decomposition process, and may clog the soil matrix with solids, such that physical filtration through the soil layers is hindered.

Insufficient aeration in the drain field soil, due to high organic content, compacted soils, or high water table, may result in anaerobic activity in the drain field which further degrades the soil.

Conversely, coarse sand and gravel soils may allow the effluent to percolate too rapidly down through the soil without allowing time for aerobic decomposition or sufficient filtering

b. Limitations in Lakefront Situations

When properly designed, sited, installed, and maintained, on-site septic systems can provide effective waste treatment and disposal.[62] Efficiency depends upon tank size, field area and capacity, amount and frequency of use, slope of the land, soil type and drainage, depth to ground water, and proximity to lakes or streams.[21]

Problem area for septic systems in Leelanau County tend to be concentrated around lakes which often have coarse sand and gravel soils.[37] Depth to ground water is often shallow.[62, 37] Septic systems are often in close proximity to the lake shore due to small lot sizes. The soils around Lime and Little Traverse Lakes are generally sandy, with relatively poor filtering capacity due to coarse texture. For proper filtering, the water must percolate down through the soil at a rate of 6 to 90 minutes per inch, and the water table must be at least 60 inches below ground level.[71] County health codes require that drain fields be at least 100 feet from water wells [66], and 100 feet from lakes or streams.[62]

Once liquid effluent percolates down through the unsaturated soil layers, it reaches the saturated soil of the water table, the top of which may be roughly parallel to the slope of the land. Groundwater, with any bacteria or toxic materials it contains, tends to flow horizontally along this slope, or hydraulic gradient until typically reaching an aquifer.[65] In lake shore situations the groundwater flows instead into the lake. Even properly functioning septic systems within 300 feet of the shoreline will probably allow some nutrients to enter the lake.[62] Problems can occur during peak recreational periods when crowding can lead to over-use that exceeds septic system capacity.

Nitrates and chloride ions are not effectively removed even under optimal conditions. Nitrogen is not a limiting factor in algal growth because blue-green algae are able to fix atmospheric nitrogen. But chlorides contained in household cleaning products may pose septic system problems due to their toxicity to most bacteria.[67]

Soluble or orthophosphate phosphorus entering the lake is of great concern because, in Michigan, it is a limiting factor in production of algae and aquatic plants. Recycling of phosphorus through aerobic decomposition and sometimes anaerobic reaction in bottom sediments can cause algal blooms, smells, reduce lake clarity, and lower dissolved oxygen in the lake.

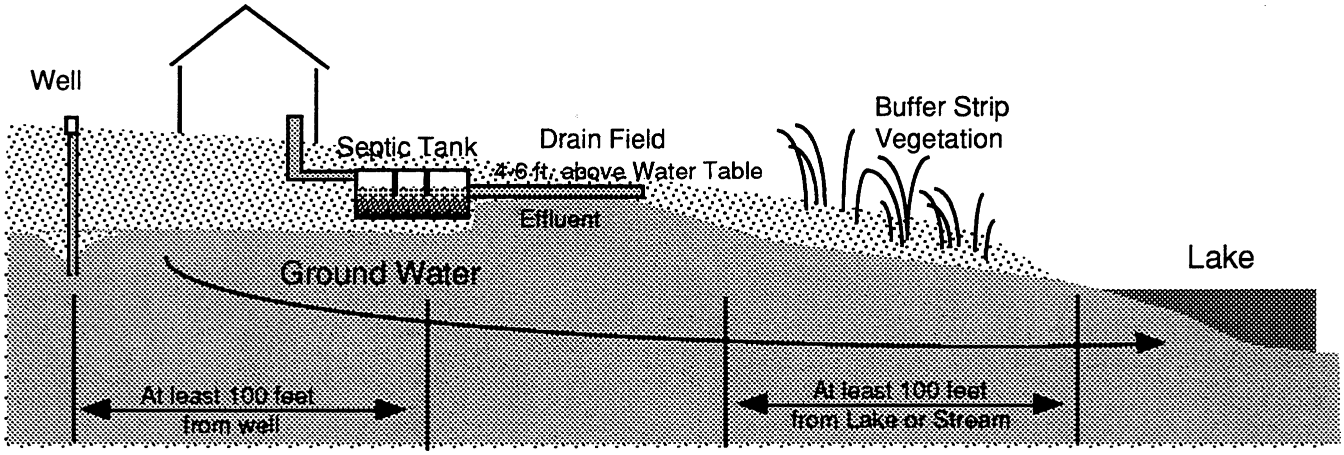


Figure 39: A Typical Septic System

c. Care and Maintenance

Septic systems have a working life of usually 20 to 30 years depending on design, siting, soils, maintenance, and usage, as discussed earlier. Systems installed before 1975 may be questionable. One common problem is a saturated drain field which results in the clogging of subsoil surfaces by organic matter. This can usually be avoided by pumping the tank every 3 to 5 years.[62] Table 15 shows estimated pumping intervals based on the size of the septic tank and the number of people in the home.

Table 15: Septic tank pumping intervals.[36]

Tank Size (Gallons)	Number of people (year round residents) 1	2	3	4	5	6	7	8	9	10
500	5.8	2.6	1.5	1.0	0.7	0.4	0.3	0.2	0.1	
700	9.1	4.2	2.6	1.8	1.3	1.0	0.7	0.6	0.4	0.3
900	11.0	5.2	3.3	2.3	1.7	1.3	1.0	0.8	0.7	0.5
1000	12.4	5.9	3.7	2.6	2.0	1.5	1.2	1.0	0.8	0.7
1250	15.6	7.5	4.8	3.4	2.6	2.0	1.7	1.4	1.2	1.0
1500	18.9	9.1	5.9	4.2	3.3	2.6	2.1	1.8	1.5	1.3
1750	22.1	10.7	6.9	5.0	3.9	3.1	2.6	2.2	1.9	1.6
2000	25.4	12.4	8.0	5.9	4.5	3.7	3.1	2.6	2.2	2.0
2250	28.6	14.0	9.1	6.7	5.2	4.2	3.5	3.0	2.6	2.3
2500	31.9	15.6	10.2	7.5	5.9	4.8	4.0	4.0	3.0	2.6
Note: More frequent pumping is required if a garbage disposal is used										

Grease, oil, solvents, corrosive and caustic agents can destroy beneficial tank and soil bacteria and hinder the filtering function of the soil. The cellulose fibers in sanitary napkins, disposable diapers, paper towels, and cigarette filters can eventually clog drain field pipe or tile openings and soil spaces.[62]

Some companies offer additives which claim to eliminate the need for pumping. A septic pumping firm should be consulted before using additives, to avoid damage to the system. Additives may kill bacteria needed for decomposition, or allow sludge in some form to enter and clog the drain field.[62]

Failure to have the septic tank pumped can result in sludge overflowing into the drain field, which can then become clogged beyond repair. A badly clogged drain field may have to be relocated.[66] When replacing a drain field or building new, consider building two small drain fields with a valve that allows diversion of waste, first into one field for several years, then the other while first one unplugs naturally.

There are a number of visible signs to alert the home owner to a malfunctioning septic system. Odors after a heavy or prolonged rains are an obvious sign. Sewage effluent may ooze to the land surface or be visible at the waters edge. There may be excessive plant and algae growth in the water at the beach. One common indicator of pollution is Cladaphora algae, a long, feathery, green algae that attaches to rocks, and dock posts. It often indicates areas of excess nutrient influx. The marl bottoms of both Little Traverse and Lime Lakes make conditions inhospitable to Cladaphora, which in turn can make it difficult to see early signs of nutrient loading. Surface wetness or ponding, and lush patches of lawn may also be indicators. The soil profile can be checked with tube-type soil sampler.

Aside from the observable signs of septic system failure there are measurement devices for assessing the operation of the system. A Septic Leachate Detector (SLD) consists of two instruments: a fluorometer and a conductivity meter. The fluorometer can be adjusted to detect the light emission characteristic of a particular substance indicating its relative abundance in the water. This allows one to check for products of human waste, surfactants or whiteners found in cleaning products.[62] A conductivity meter measures ability of water to conduct electricity. This is used to indicate concentrations of dissolved substances. The surface water should be tested for up to six parameters: ammonia-nitrogen, nitrate-nitrogen, total phosphorous, chloride, detergents and fecal coliform, as indicators of proper treatment of effluent.[62] A shallow well point sampler and hand pump can be used to extract ground water for testing. Testing ground water is preferable to testing surface waters because the pollutants in ground water move more slowly and are not diluted by waves and currents. A conductivity reading higher than that of local ground water, in conjunction with high fluorometer readings, could indicate septic leachate.[62]

Shallow drain fields can also be damaged by driving over them with heavy vehicles or equipment. The pressure can crush or dislodge the tiles. Drain fields seldom freeze, but they can in very cold weather, particularly if the home is unoccupied during the winter months. Freezing and thawing can crack the tiles and heaving ground may dislodge them.[67]

The Leelanau County Health Department amended its health code in 1993 in an effort to bring older septic systems up to departmental standards. This was done under expanded authority of the Michigan Environmental Protection Act, MCL 691.1201. The new code requires inspection of septic systems and wells prior to the sale or transfer of property and mandatory upgrades of substandard systems.

d. Water Use and Water-saving Appliances

Heavy water use can reduce the amount of biological treatment which occurs in the septic tank by overloading the drain field soils.[62] Soils that are waterlogged for an extended period promote anaerobic digestion of effluent, further damaging the soil structure. Large volumes of water also flush un-decomposed and un-filtered effluent through the soil. This can be avoided by using common sense in restraining water use, especially after heavy rains have saturated the upper soil layers or raised the water table. Stagger showering times and wash laundry in smaller loads over a longer period of time. Garbage disposals put unnecessary organic solids into the system. Dishwashers use an unnecessary volume of water compared with hand washing. Toilet tank floats can be adjusted, or a brick can be placed in the tank to reduce the volume of water flushed.

2. Holding Tank Systems

Some properties lack suitable soil, setback distance, have inadequate depth to ground water or are otherwise unsuitable for installing a septic tank and field system. Property owners may consider a holding tank. Periodically, wastes are pumped from the tank by a contract disposal service and taken either to a municipal sewage treatment plant or an approved land disposal site. Holding tanks work best in conjunction with water saving plumbing devices to reduce volume. Existing septic systems can also be converted to holding tanks, usually by addition of greater tank capacity. The existing drain field may be usable as a backup measure in case of tank overflow.[21]

Some disposal services offer flat rate haulage fees for regular scheduled pumping. The cost of the service averages about $1000 per year for a family of four, according to a Wisconsin study . Where there sufficient numbers of holding tank users, group rates can sometimes be arranged.[21] The University of Wisconsin is investigating the concept of on-site waste disposal municipal authority. A local municipal authority assesses properties and purchases the septic systems of all member households, assuming responsibility for operation and maintenance of the systems including replacement or conversion to holding tanks.[21]

3. Lakefront Sewer Systems - Pro's and Con's

There are currently no plans to install sewer systems around either Little Traverse or Lime Lake. The low population density relative to the great distance around the lake perimeter makes sewer lines economically not feasible.[37] Sewer systems may be necessary around an inland lake to solve a water quality problem, but are generally better suited for dense new developments.[71]

4. Self Contained Systems

Alternative self contained systems include the relatively recently developed propane incinerator toilet and the "Clivus Multrum" dry organic composting toilet. Another type is the mineral oil recycling flush system, having the advantage of reduced liquid volume and holding tank pumping frequency.[21]

The disadvantages of these systems are high initial costs, typically $800 to $4000, plus maintenance and operation costs for pumps and filters, propane and/or pumping fees.[21] These systems have not yet gained wide acceptance.

B. Lawn Care and Grounds

Natural shoreline vegetation prevents surface soil erosion and protects the lake from excessive nutrient input which can degrade water quality. Generally a turf type lawn without a protective greenbelt along the shoreline produces more surface runoff of nutrients and sediments than a forested landscape.[62]

1. Lawn Maintenance Fertilization

Lawn fertilizers and pesticides can have an adverse effect on water quality, especially if used improperly. In general, lawn fertilization should be kept to minimum. Before fertilizing, test the soil to determine if you need fertilization, and with which nutrients. Test kits can be obtained from the Cooperative Extension or Soil Conservation District.

Most lawns in Michigan do not need additional phosphorus found in most fertilizers. Lawns that slopes steeply toward the lake, or lawn areas within thirty feet of the water are susceptible to movement of phosphorus into the lake by seepage into the groundwater or by surface runoff.[66] Fertilizer bags list ingredients as relative weight of nitrogen, phosphorus, potassium, in that order (for example 25-10-5). Four to six pounds of nitrogen per thousand square feet of lawn per year is adequate. It should be spread in multiple applications and only in the spring when plant growth is rapid. Applying too mush at one time can actually damage the lawn, and the excess may run off into their lake. Fertilization should be avoided in late fall when the lawn is not taking up nutrients.[66] Nitrogen produces dark green foliage in some grasses, particularly the nutrient demanding Kentucky bluegrasses. A coarse fescue is naturally a lighter green, requires less nutrients, and is much more drought resistant. The dark green lawn can become a nuisance if it provides more nutrients for algae.

2. Erosion and Shoreline Stabilization

Maintaining the shoreline is a problem for many riparian home owners. Development may have occurred on highly erodable soils, such as wetland mucks or sand dune soils. Subsequent erosion is unsightly and degrades the landscape. Resulting turbidity clouds the water with suspended solids while heavier sediments accumulate on the lake bottom.

Man-made structures such as rip-rap or bulkheads of concrete or steel are popular methods of shoreline erosion control.

Rip-rap is generally quarried rock which is placed along the shoreline. It is often used after natural vegetation has been removed and wave action erodes the shoreline. Rip-rap looks out of context with the natural lake shore. If its use is deemed necessary, a combination of local stones and boulders is preferred, with native vegetation planted in the crevices to blend the rip-rap with the natural surroundings.

Permanent bulkheads and revetments excavated into the substrate require a $25 permit from the DNR under Act 346. As of February 1990, structures exceeding 200 feet in length also require a public hearing.[66] The Soil Erosion and Sedimentation Act requires a DNR permit for grading or excavation within 500 feet of lakes or streams. Dredging a channel to make shoreline access for boats is illegal without a permit.[66]

Both shoreline erosion and dredging issues are raised when lake water levels fluctuate greatly. Some homeowners have bought property when natural groundwater and lake levels were high, and some when levels were low. Problems arise when conditions reverse. Human alteration of Lime Lake levels through damming of Shetland Creek is currently controversial. Fluctuating water levels can also kill specially adapted plants and animals found in adjacent wetlands. Their survival often depends on micro-topography or a slight changes in elevation relative to the saturated soil zone. Altering lake levels may drain or flood these wetland soils.

3. Footing Drains/ Roof Runoff

Surface runoff includes roads and driveways, patios, roofs and down spouts. Road drainage ditches should not directly flow into lakes or streams. Roadway runoff is often contaminated with oil, gasoline, coolant and other toxic chemicals. Driveways and patios should be graded to direct runoff away from the lake, and away from the septic drain field. Runoff from roofs flushes into eaves and through down spouts should also be directed away from drain fields. Otherwise the sudden influx of water can flood the drain field. Water should be directed to a water detention area if possible. Detention basins are low ponding areas created to hold water temporarily, allowing it to seep into the ground. Dispersed sheet drainage reduces flow velocity and erosion potential, as opposed to concentratd flow through swales or ditches.

Sub-surface drainage such as drainage tiling or perforated piping along house foundations should be kept at least 100 feet from drain fields or lakes.[66]

4. Green Belts / Buffer Strips

Ideally, all properties should have at least a "green belt" of natural vegetation along the lake shore, separating the lake from the house, septic field, and lawn. A green belt is a vegetative strip of aquatic plants, emergent plants in the shallows and on land, and terrestrial ground covers, shrubs, and trees.

Aquatic macrophytes are higher plants serving essential functions in the lake ecosystem. Plant photosynthesis oxygenates the water, and plant structures provide food and shelter to fish and other wildlife. Emergent vegetation are shallow water rooted plants which extend above the water surface. These aid in stabilizing the substrate and intercepting nutrients in land surface runoff. They also reduce the effects of erosion by wave and ice action. Although considered a nuisance by many boaters and swimmers, removal of aquatic "weeds" destroys fish and wildlife habitat.[21, 64]

Root systems of terrestrial plants stabilize the shoreline banks against erosion by wave and ice. Groundcovers, shrubs, and trees trap and filter sediments more effectively than turf grass lawns. A combination of deep and shallow rooted plants is ideal. Ground level ferns, creeping vines, sedges, rushes, and native grasses slow the rate of surface runoff and prevent soil erosion. An upper soil layer of decomposing organic leaves, twigs, roots, and fungi also slow the rate of runoff by both physical size and by maintaining moisture and aeration in the upper soil layer that acts as a sponge. Trees and shrubs with extensive root systems can take up excess water and nutrients before they reach the ground water. Some plants that grow in saturated soils, such as willows, should be kept away from septic fields.

Attractive natural landscaping can enhance the aesthetic and resale value of a property, while preserving the local and regional scenic character. Wildlife benefits from the diversity of habitats offered by various canopy layers of overstory, understory, and ground cover. A patchwork of dense cover and open areas with access to fruits, seeds, and nuts is often desirable for wildlife diversity.

Views to and from the lake are components of visual quality. Homeowners can use vegetation to "frame" views onto the lake, by selectively trimming lower tree branches and thinning shrub density. It is important to be aware of ultimate size of growth and take advantage of various canopy heights. Sparse branching and foliage provide filtered views through to the water, while dense branching or foliage are best for privacy screening. Greenbelts can allow good visual access from the house or yard, while at the same time leaving a relatively natural view of the shoreline from the opposite shore or from boats on the lake.

New development should leave as much existing native vegetation as possible. To create a view of the water, trimming or removal of a few trees may be necessary, but disturbance to the ground beneath the trees should be avoided. Grading often exposes or suffocates sensitive surface roots, leading to disease or eventual death of the tree.[66] Lawn area should be minimal. Reduction of lawn area also reduces fertilizer, pesticide, and maintenance requirements, assuming that disease prone and high maintenance ornamental species are avoided.

Homeowners seeking to learn about native greenbelt species should compare their site with undeveloped natural sites as to soil drainage and moisture content, depth to water table, slope and orientation to the sun. They should note how undeveloped sites have native vegetation holding the soil at the waters edge. Occupied sites with lawns often display bare soil erosion, with rip-rap or retaining structures at the waters edge.

Indigenous species should be obtained either from local growers or from one's own property. Removing wild species from public land is a violation of state law.

Many introduced plant species (and some native ones) can become very intrusive. These "invasive" or "exotic" species can be particularly troublesome because the habitat conditions or pests which control them may not be found in this country. One such problematic invader which has been planted extensively in the U.S. is Purple Loosestrife *(Lythrum salicaria)*, from Europe. Today this plant is choking out many native species such as Cattails (*Typha spp.*) around water bodies. It is pretty in bloom, but it provides little food and habitat for native wildlife, and it is nearly impossible to eradicate. Unfortunately, the Soil Conservation Service (SCS) and other state agencies recommend several invasive pest species for wildlife value or erosion control. The project group advises that several of these species are known pests in the lower peninsula of Michigan, and should not be planted: Buckthorns *(Rhamnus cathartica and R. frangula)*, Tatarian Honeysuckle *(Lonicera tatarica)*, Halls Honeysuckle *(Lonicera japonica)*, Autumn Olive *(Eleagnus umbellata)*

The masters project group has compiled a database of native plant species appropriate for riparian greenbelt strips. A hard and soft copy will be provided to the Leelanau Conservancy for anyone who would like to plant a native greenbelt. An example of the database is in Appendix C.

5. Yard Waste

Waste paint , oil, and other household products or containers should never be dumped into or adjacent to lakes, streams or wetlands. They are toxic and can kill plants and animals, enter ground water or wash into the lake. Kitchen garbage, lawn clippings, and leaves release nutrients as they decompose. It is best to compost them as far as possible from the water's edge. Leaves should never be raked directly into a lake nor should they be burned along the shore. The ashes contain nutrients that should not enter the lake.[66]

6. Underground Storage Tanks

Old buried farm and residential fuel storage tanks may contaminate ground water if they develop leaks. Tanks smaller than 1100 gallons are not inventoried by the State of Michigan. Taken together these can threaten ground water quality and perhaps eventually enter the lakes.[37]

7. Waterfowl Feeding

Many people enjoy seeing ducks, geese, and swans on the lake, and encourage them by feeding. Feeding encourages them to remain at one location, creating nuisance populations. Waterfowl manure contains large amounts of nitrogen and phosphorus, contributing to algae growth and odors.[66] Merganser ducks at Lime and Little Traverse Lakes are alternate hosts to the parasite that causes swimmers itch. A program of waterfowl immunization and removal has been successful in reducing residents' reports of swimmers' itch [35]

V. Responsible Inland Lake Development

According to some of the property owners, "insensitive development" is occurring along the shorelines and ridges of Lime and Little Traverse Lakes. Most of the existing development consists of small cottages and homes which date back at least 25 years. The areas which were developed during these earlier years meet the physical and functional needs of both the human and natural systems. Thus, the two environments harmoniously coexisted as a single system. This type of bond, where man and nature compliment each other, represents sensitive development along the lake shore. In recent years, this bond has been the exception rather than the rule. The majority of the new development, (within the past 10 years), represents an attitude that clearly sacrifices the needs of the landscape to the perceived benefit of man. The goal of this section is to promote the idea of man being part of nature, rather than man versus nature. Guidelines are also presented for individual lakefront property owners in order to encourage the preservation of a single fragile ecosystem.

A. Methods

The research, which was conducted on the subject of development, has been divided into four separate, but related categories. These categories, (Visual Assessment, U.S. Census Data, Local Concern and Environmental Concern), provide the necessary information to achieve the goal of man being part of nature.

1. Visual Assessment

Visual assessment was conducted by land, water and air (aerial photos). Photos were also taken to capture the landscape perceived by the viewer and as a matter of record. The shorelines were assessed based on the "Expert Paradigm" and the "Psychophysical Paradigm" and a comparison with a fully developed inland lake located in southeastern, Michigan.[59]

Since visual assessment can be rather subjective, one needs to set a standard or base for comparison. The base chosen for this comparison was an inland lake located in southeastern Michigan, near Adrian. Devils Lake is highly developed and extensively used for recreational purposes; especially, during the months of June, July and August. Residence structures have small setbacks with turf lawn transcending from the structure to the shoreline. On the majority of the properties there is little or no vegetative buffer beyond the turf between the structures and the water. Therefore, one can see almost every structure from the waters edge as well as a large number of seawalls and docks. The amount of development shows man's dominance over the landscape. Is this what lies in the future for Lime and Little Traverse Lakes?

The two processes utilized, the "Expert Paradigm" and the "Psychophysical Paradigm", were used simultaneously to create a more complete analysis of the study areas. "The Expert Paradigm is derived from two general intellectual traditions: (1) the fine arts and design, and (2) ecology and resource management. The first, (1), depends heavily on formal landscape architecture criteria: scale, boundaries and edges, land form, plant cover, water elements and focal attractions. The second, (2), assumes that natural, unmodified ecosystems have the greatest intrinsic aesthetic quality." [59] Evaluations conducted within the "Expert Paradigm" are also completed by skilled experts or others given specific training to enable them to conduct valid assessments.

The analysis is made more complete by incorporating the thoughts of the local property owners who had a specific interest in this assessment, (the process known as the "Psychophysical Paradigm"). The "Psychophysical Paradigm" was utilized for its ability to represent the perspective of the general public. The foundation of this paradigm is based on the notion that "landscape perception is an emotional, subjective, reaction on part of the general public."[59]

"The Psychophysical Paradigm's special strength has been to widen the base of scenic assessments, by measuring the aesthetic values of the general public, (as it relates to the landscape)." [59] This was performed through the use of surveys in which the property owners could indicate concern for potential damage to the scenic views surrounding the lakes. These two paradigms, when used in combination, represent a broad view of landscape perception, from the expert to the average citizen.

2. Census Data

U.S. Census data allows for predictions regarding future growth and trends of the Lime and Little Traverse Lake environments. By charting the past, present and future population trends of the county and the townships, one can begin to make assumptions regarding the future of increasing development in the two study areas.

3. Local Concerns

a. Property Owners

Data was collected from a variety of sources regarding the current status, concerns and trends as they relate to the human and natural systems. Communication with local residents and lakefront property owners was crucial in developing successful guidelines. This communication allowed identification of major concerns of property owners regarding threat associated with development on the lake environment. Two opportunities to voice these concerns were made available to the property owners:

• Project objectives and goals were presented at scheduled lake association meetings in each area. This provided lake association members an opportunity to alleviate any fears of this being a "policing" group, and led to a free discussion of ideas. The objective of gathering information in order to create a public document will in turn educate individuals about the quality of the lakes ecosystems. This helped gain public support for continued research. One-on-one discussions were also available to interested people after the conclusion of the meetings.

• Communication with residents was also obtained in a survey format. The surveys satisfied many objectives which included: quantitative data from the property owners perspective, anonymity of the residents, and it introduced the project to residents who did not attend the lake association meetings. Question #15 of the survey deals directly with the people's response to the development pressure being placed on the inland lake environments. These concerns included: the threat of keyhole development, increased fishing, degradation of water quality, damage to the scenic nature, and the degradation of animal habitat. Space was also allotted on the survey for people to write in additional concerns (see Appendix A).

b. Government / Policy makers

Contact with the county planner and Land Conservancy provided data and documentation regarding current county and township ordinances and proposals. This information allows one to see the perspective of local government with regard to development issues.

4. Environmental Concerns

Environmental concerns are based on visual assessment techniques, the concerns listed by local residents and property owners and pertinent literature. These combined processes address how development affects the natural system, and thus allows for the development of guidelines. The guidelines in this section will inform individuals about the preservation of natural systems during the process of construction.

B. Results

"The primary means by which people sense the physical environment is through vision."[58] Limited amounts of research have been conducted on how development, nature and visual quality relate to one another. In combining these design criteria, the resulting guidelines are provided to encourage sensitive development around the two inland lakes. Furthermore, the development guidelines can also be applied to similar lake environments.

The issues of concern are based on four separate, but related design inputs. The arrangement of these results are not presented in order of importance, rather they are listed in terms of actual execution. These four design inputs are *visual assessment, U.S. Census Data, local concern and environmental concern.* Each input provides information necessary for the simultaneous consideration of development and the natural system which, in turn, relates directly to visual quality.

1. Visual Assessment

a. Residential Development

Upon visual assessment of Lime and Little Traverse Lakes, there appeared to be a variety of new development occurring along the shoreline and on the nearby ridges. Although the majority of the older houses tend to fit into the surrounding environment quite well, the newer development does not. These new developments introduce a sudden lack of uniformity which is cause for concern regarding the future of this relatively pristine system.

In the two study areas, the older established cottages are tucked away amongst a natural edge. Therefore, as one scans across the lakes, the character of a natural environment allows for pleasant and uninterrupted viewing. The majority of new development, (in the last 10 years), does not fit into its surroundings. The land on which it sits has been cleared of vegetation thus disrupting the continuity of the shore and ridge line. Furthermore, these structures have become focal points in the landscape due to the lack of harmony with the existing natural setting. The objective would be to have focal points which are harmonious with the surrounding landscape.

Currently, the Cleveland Township Ordinance requires a 75' setback from the waters edge. However, there is no ordinance regarding visual quality of the proposed development in the context of its surroundings. Therefore, much of the current development occurs in a zone which is intrusive to the environment (see Figure 40). The "intrusive zone" is created by the clearing of vegetation and implementation of minimal setbacks. These actions separate the built zone from the natural zone and also allow the structures to become individual man made focal points in an otherwise natural environment.

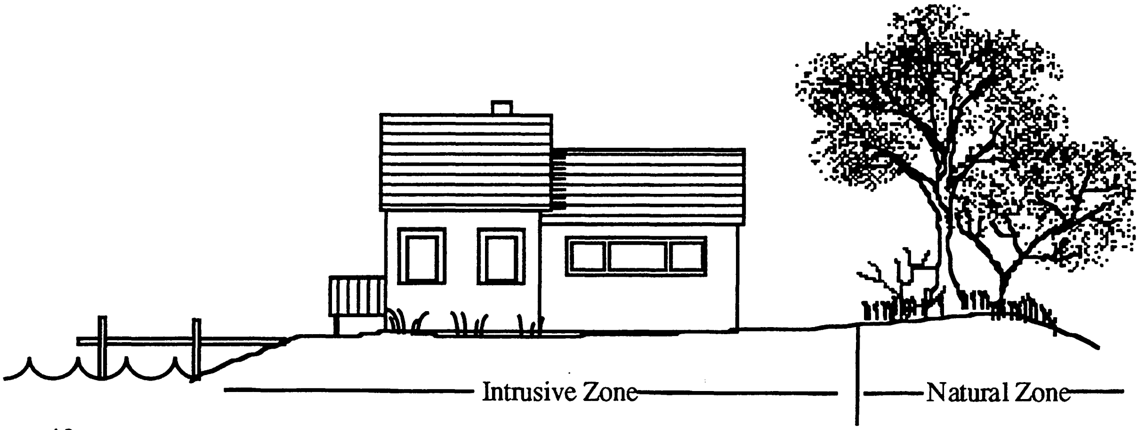


Figure 40:

Lime and Little Traverse Lakes have plenty of potential for further development. Currently, it appears that most property owners have taken special care to avoid unsightly development to insure the quality of the lake and its surroundings. The lake shore tends to be relatively flat with a ridge located at the western edge of both lakes. These two different types of topography encourage development which can reinforce the natural character of the environment. Development insensitive to this topography, however, will break the continuity of the existing landscape, thus beginning to destroy its character.

b. Flat Topography

The flat shores are dominated by masses of trees, shrub vegetation and for the most part, sensitive development. Thus, the buildings and the natural surroundings compliment each other. Some areas within this flat zone, however, contain parcels of land where the vegetation has been cleared. If this trend is allowed to continue, the landscape will be dominated by buildings and not by the character of the natural elements which most property owners seem to care for so much. (See Appendix A for survey results to question #15, "damage to scenic nature"). "As such, complete clearing of trees should be small in scale and should minimize the introduction of long straight edge lines. Complete clearing may be used to increase variety as long as its scale is in keeping with the flat shore character." [58] On the other hand, although complete clearing may be used and the flat character of the shoreline may be maintained, the "natural " character will be destroyed.

c. Ridge Topography

Beyond the flat shorelines is a ridge which is currently being lined with residential development. The ridge is a strong natural feature which provides a backdrop for the lakes. Some cottages and houses ignore the natural surroundings at the top of the ridge in order to provide uninterrupted viewing of the two lakes below. Development allowed to continue in this fashion, will degrade the visual quality from the areas below. The result will be an expanse of buildings which will change the character of the lake (see ridge development, Figure 41). This character, once changed will never return to its current state.

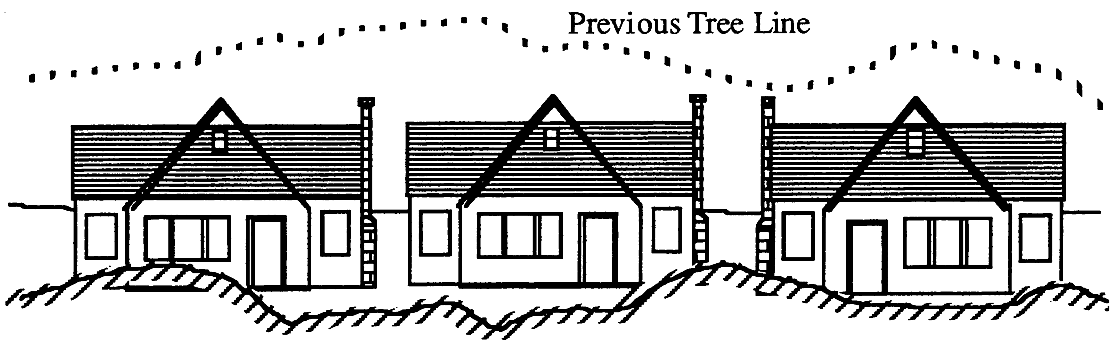


Figure 41: Current ridge development.

Developments along the ridge should also follow the idea of disturbing as little of the existing vegetation as possible. The background tree line should also be maintained so the developed areas reflect the natural character of the ridge. A vertical element in an otherwise horizontal landscape attracts a tremendous amount of attention, even if its only one structure.

"As the dominant visual element of the ridge shore is a long horizontal line, any form, line, or other element which competes with that element is undesirable. Therefore structures built on top of the ridge line should be horizontal in character to reflect the line of the ridge. Where the ridge is close to the shore, structures should be kept above the ridge line to prevent it from being blocked by development along the shore and to improve the lake views from those structures. Buildings selectively coming down a ridge to the shore can also add emphasis and variety to the environment. Similarly, vegetation can be added or removed to strengthen a ridge line or partially obscure it for variety."[58]

A conflict of interest was apparent throughout the research regarding the extent to which development influences visual quality in a natural setting. Most of the research which has been conducted up until now, is either devoted to the development of structures or the preservation of the natural environment. Very little is devoted to a combination of the two, thus calling for sensitive development guidelines. To achieve the best of both worlds, increased development and preservation of the natural character, future residential development should abide by the following guidelines:

• "*minimize clearing of vegetation and retain a tree canopy to preserve the tree form domination, and allow for development of lake views.* Any structure placed in a shoreline clearing will provide emphasis on it, if that quality is desired (see Figure 42).

Figure 42: Existing vegetation preserves visual quality.

• *maintain variety in building placement.* A high density of structural forms can overcome the tree form domination of the flat shore landscape; especially, if the structures are rhythmically placed along the shoreline to form a strong continuous line. Variable setbacks should be encouraged to promote a more natural layout. This also follows the same argument as the previous guideline. A natural environment requires variety in order to maintain its character (see Figure 43).

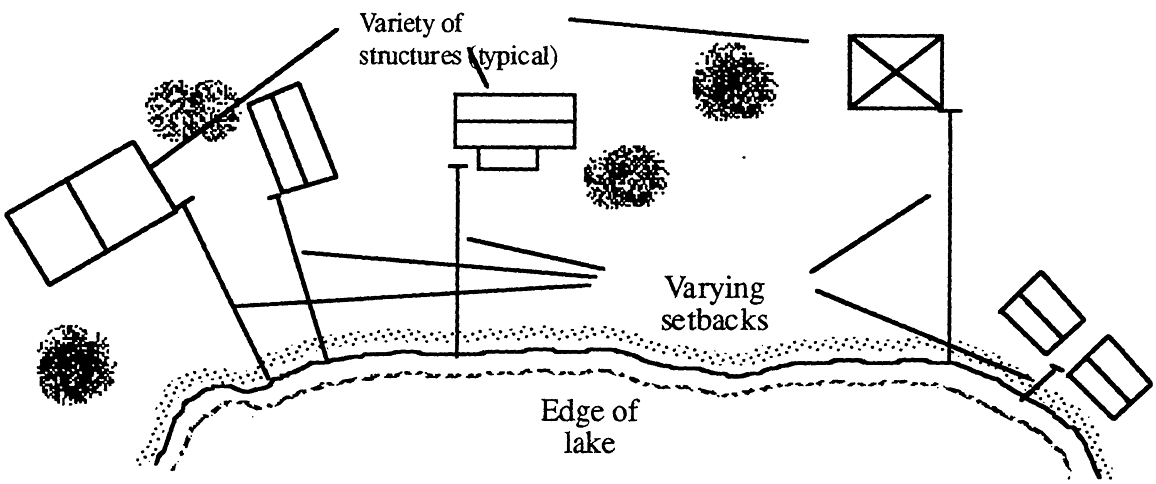


Figure 43: Varying building placement.

• *maintain diversity as natural tree forms do.* Nature is diverse; therefore if constructing in a natural environment, one should avoid designing buildings that are very similar. It disrupts the scene."[58]

d. Commercial Development

Commercial development should be kept to a minimum within the view of lakefront property owners. This will help to maintain the horizontal/natural character of the landscape. If commercial development is to occur, the guidelines for residential development should be followed. In addition, guidelines particular to commercial development include:

• *limiting building heights* . The structures should keep in character with the neighboring residents, one to two stories.

• *limiting the amount and types of signage which promotes the individual establishment.* There should be no neon signs, and also a height limitation. The height should not exceed that of the building. Illumination of signage shall be by fluorescent or incandescent lighting only.

• *locating parking away from the water's edge.* This will not only help maintain the current visual character of the lake shore, but also help to maintain the environmental/water quality.

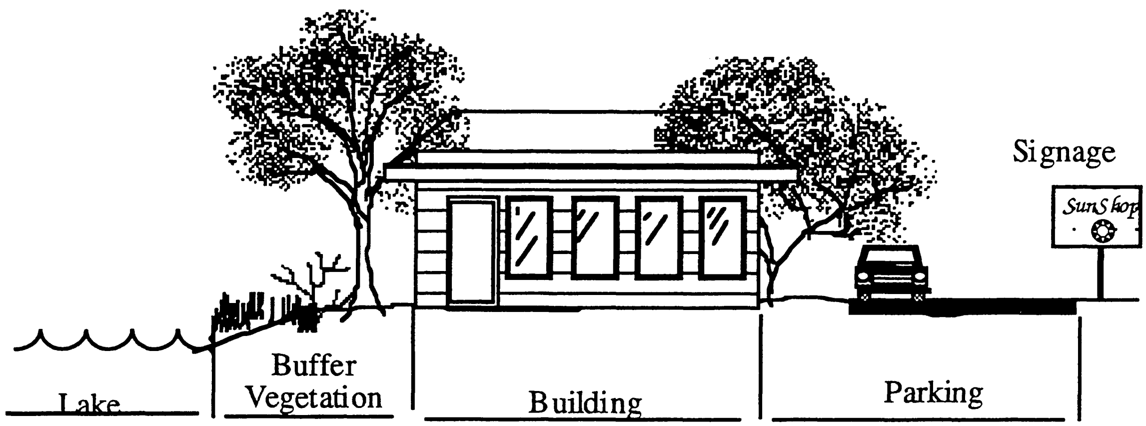


Figure 44: Commercial development.

2. Census Data

The U.S. Census data is an important source when examining any process that involves the presence of humans. This data contains important information regarding the history of population trends. According to the U.S. Census, from 1940-1990, Cleveland Township has experienced a 115% increase in population. From 1980-1990 the population increase was 30%. Table 16 illustrates the history of population change from 1960-1990 for all townships located in Leelanau County. Many of the surrounding villages and townships have also experienced similar increases to Cleveland Township. This data is of particular interest since population increase is directly related to increase in development. As one community experiences growth in development, others tend to follow that pattern. For instance, the increase in Cleveland Township's population is partly due to the increase in the development of the surrounding communities. A significant percentage of people live in Cleveland Township, but work in the neighboring communities. According to the 1990 U.S. Census data, the number of Cleveland Township commuters was 39%. This information illustrates that the communities are directly related. Other census statistics are also important in determining who makes up the population.

Table 16: Population Statistics for Leelanau County.[61]

Leelanau County Population Statistics 1960 - 1990						
	Census				% Change	
	1990	1980	1970	1960	1980 - 1990	1960 - 1990
County Total	19,150	15,462	12,397	10,720	24	79
Bingham Township	2,051	1,546	916	625	33	228
Centerville Township	810	709	473	577	14	40
Cleveland Township	851	654	393	288	30	195
Elmwood Township	3,425	3,004	2,240	1,687	14	103
Greilickville CDP	1,134	N/A	N/A	N/A	N/A	N/A
Empire Township	872	797	956	824	9	6
Empire Village	361	340	409	448	6	-19
Glen Arbor Township	630	578	571	431	9	46
Kasson Township	1,067	952	676	640	12	67
Leelanau Township	1,694	1,560	1,270	1,189	9	42
Northport Village	591	611	594	530	-3	12
Leland Township	1,668	1,446	1,219	1,229	15	36
Solon Township	1,268	987	798	701	28	81
Suttons Bay Township	2,150	1,774	1,360	1,130	21	90
Suttons Bay Village	578	504	522	421	15	37

Four population projection methods and their associated county projection for the year 2000 are shown in Table 17 . In addition, "The Leelanau General Plan" includes population projections for the county based on an average of these four sources. The U.S. Census does not take into account the seasonal population. Therefore one cannot rely solely on this data when making future predictions about growth and the impact of development. This is due to the fact that many land owners may not have their primary residence on the lake. The 1990 Leelanau County seasonal population is estimated at 115,689 persons. The projected population growth for the year 2000 in this sector is estimated at 150,416. Figure 45 represents the percentage of seasonal housing units in each of the communities within the county. The General Plan also indicates that the projected increase in housing units, (from 1990-2000), for Cleveland Township is 164. Of this total, 90 units will be year-round residences while the remaining 74 will be seasonal homes.

The implications of this data for man and nature are clear; however, what does this mean in terms of visual quality? These projections for increased development stress the importance of the need for greater emphasis on planning and guidelines. The current attitude toward insensitive development in combination with a continuous increase in development will destroy the natural setting in which the lakes are currently located. Therefore, all guidelines related to development, the preservation of the natural setting and visual quality should be implemented into the site plan review process and enforced by the appropriate authorities.

Table 17: Leelanau County Projected Population 1990-2000.[44]

Projection Method	Projection	Projected Change 1990-2000
State of Michigan Department of Management and Budget (Adjusted from 1990 Census Data)	19,846	20%
"Straight Line" Projection	23,000	39%
County Solid Waste Plan (average)(medium=20,431; high=25,754)	23,093	40%
Application of the Average Percentage of Increase Each Decade Since 1960 to the 1990 Population (21.1%)	20,014	21%
Average of All Four =	21,488	30%
1990 Leelanau County Population = (Townships Only, does not include Villages)	16,527	N/A

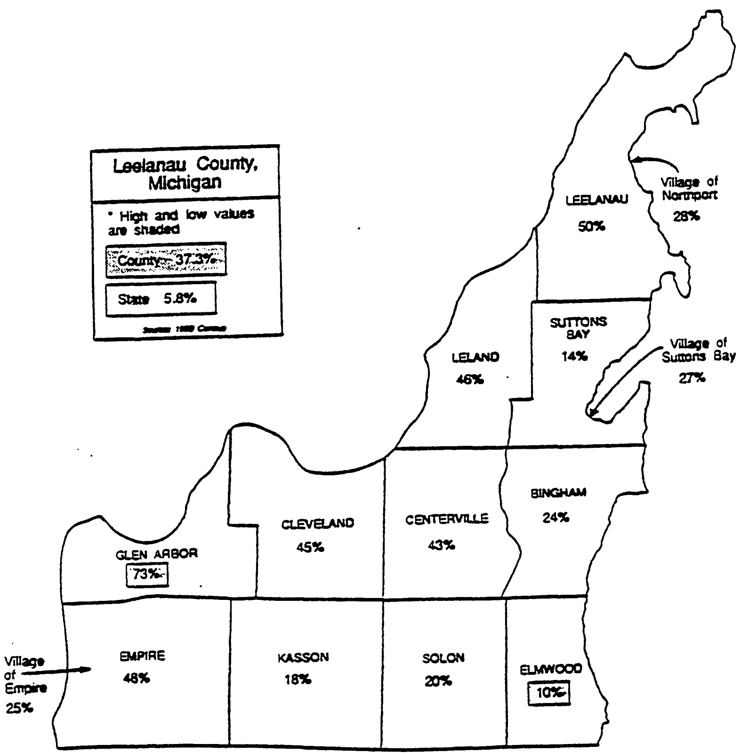


Figure 45: Percentage of Seasonal Housing Units (1990).[44]

3. Local Concern

The support of the community is a critical element when considering policy changes that will affect each citizen and their property. Broad-based support from these people will provide the impetus to the local policy makers, who represent them, to implement more sensitive policies reflective of their concern. Specific concerns of the local community were obtained through a survey distributed to each of the addresses surrounding the lake. The content of survey questions ranged from septic tanks issues to the scenic quality of the landscape, (see Appendix A for survey sample and results). Although the survey was far from complete in determining a visual assessment by the "general public", a general sense of concern for the visual quality of the natural environment was perceived. In addition to the use of surveys, presentations at the annual lake association meetings were made to inform members of research that was to take place in and around the lake. Members were also allowed to voice their concerns to the research group on a one-on-one basis.

Based on the vocal and written concerns of the residents and the Leelanau Land Conservancy, the two lakes were analyzed in terms of their natural character, vegetation inventory, water and scenic quality, and how humans have impacted this ecosystem. According to the survey results, the two main concerns which require special attention are keyhole development and damage to scenic nature.

a. Keyhole Development

Based on survey responses, keyhole development was a major concern of lake area residents. This type of development " provides access to a large number of residents through a small amount of commonly owned shoreline. This, along with existing development, can exceed the physical and environmental carrying capacity of the lake. This threatens to reduce enjoyment of the lake for boating, fishing and viewing, and undermine the area's ecosystem." [66] For these reasons, keyhole development is discouraged as part of the construction growth around the lake. Currently, this type of construction has not overrun the lake, and boat levels are at a desirable level due to the relatively small size and shallow depth of the lakes. The watershed is a very fragile system which cannot handle high density development. This type of development reduces the visual and environmental quality of the lake and its edge.

Many of the property owners mentioned that the threat of keyhole development should not be of concern. They stated that the "Township Ordinances" and the "Lake Associations" would not allow this type of development to take place. According to the Department of Natural Resources, "Lake associations exist in many of the lake communities in Michigan. The associations provide a forum to educate property owners about various legal, recreational and ecological issues, and a resource of money and energy to solve problems." [66] The Department of Natural Resources does not mention anything to the effect that Lake Associations and/or

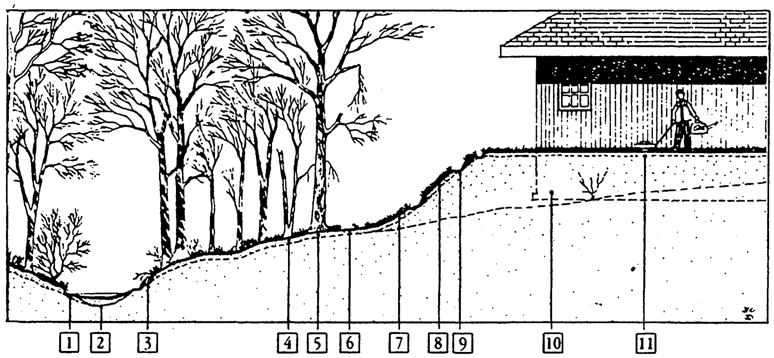
Townships have the authority to prohibit keyhole development. This conclusion is based on a case study in which a developer, Fox Associates, took Hayes Township to court for prohibiting a proposed condo development with access rights to Lake Charlevoix. "Both the Supreme Court and the Court of Appeals ruled that townships have no authority to impose keyhole controls, carrying capacity restrictions or any other limits on riparian rights under The Township Rural Zoning Act." [66]

A township and/or lake association can try to deter keyhole development through various tactics, but they cannot legally prohibit it. There are many factors involved in keyhole developments which make each case unique. Thus the courts may not always rule in favor of the developer, but the townships and lake associations are fighting an uphill battle. One way to discourage developers is the use of a ratio in terms of dockage in relation to lineal footage of shoreline. In a keyhole development, this would allow only a small amount of dockage to be used for a large number of people. The threat of court action can also be a deterrent. By delaying construction through potential court delays, a developer may lose interest and decide it is not worth the time and money.

4. Environmental Concern

Environmental concern could arguably be the most important concern regarding development, nature and visual quality. The natural environment is the base on which development occurs. Human infiltration and manipulation of this natural environment has a direct effect on the environment both functionally and aesthetically. The inland lake ecosystem is extremely fragile and the soils tend to be highly permeable. Therefore, the potential for contamination of surface and ground water is extremely high. Precautions must be taken in order to prevent environmental damage to these important resources.

In "Livable Landscape Design", Collins and Adleman provide a pictorial description of typical environmental damage (see Figure 46).[13] These points of concern set the stage for three main issues: erosion control, runoff and construction.



1 Erosion of swale banks
2 Siltation of swale (pollution of streams)
3 Loss of protective vegetation
4 Creation of a lawn under trees changes pH and moisture levels
5 Trees damaged by grading equipment
6 Severe compaction caused by grading equipment
7 Fill over roots cuts off oxygen and water
8 Steep slope needs high-level maintenance
9 Erosion is a constant problem
10 Potential for settlement when building on fill
11 Unnecessary lawn requires high maintenance

Figure 46: Typical Environmental Damage.

a. Erosion Control

There is some visible erosion along the banks of the lakes which is being controlled in many different ways. Erosion is caused by removal of aquatic and terrestrial vegetation, dramatic changes in the lake level, and the freezing and thawing processes of the lake. Also, storm water runoff from roads, roofs, driveways, patios and unvegetated soils can cause erosion if not properly directed, (see runoff). In the long term, erosion can decrease the value of the property and also detract from the visual quality of the shoreline. To avoid or repair erosion damage one should consider implementing the following guidelines:

• *plant a vegetative buffer strip between their residence and the water's edge.*

• *allow aquatic plants to grow* . This will provide a wave energy reducer.

• *vegetate bare soils in order to reduce the potential for runoff.* This can be done through seeding, or planting a variety of species, (see section devoted to buffer strip).

b. Runoff

Storm water runoff should be directed away from the lake and septic fields before, during and after construction. Flooding a septic field can release pollutants which can flow into the lake thus causing harm to the water quality and its inhabitants.

If at all possible, water should be drained into a retention area where the water can be released slowly into the ground, thus allowing pollutants to be filtered through the existing soil and vegetation.

All lake area residents are dependent on ground water for potable, (drinking), water from an on-site well. The Lime/Little Traverse Lake areas, like all lake ecosystems, are very sensitive to the threat of drinking water contamination. This can be a serious problem mainly because the soils found in these types of ecosystems are highly permeable. Therefore, filtration of pollutants being dumped knowingly, or unknowingly is limited by vegetation and retention ponds.

c. Construction

Although development has continued around the lake for a long time, it is becoming more and more apparent that development is beginning to put pressure on the quality of the environment. Therefore there should be certain guidelines that individuals practice when constructing new buildings, additions, or reconstruction of existing buildings. Prior to construction, it is important to prepare the site by adhering to the following guidelines:

• *protect existing vegetation from earth moving equipment and compaction of soils within the plants drip line.* This can be accomplished by using "snow" fence or other protective barriers (see Figure 47).

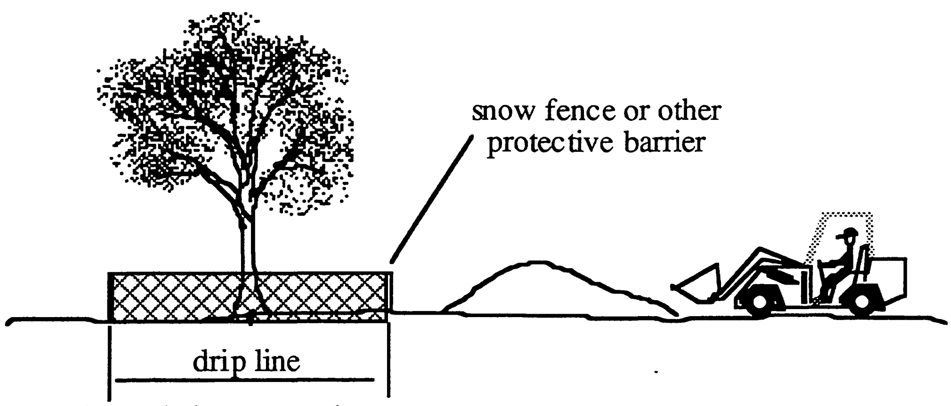


Figure 47: Protecting existing vegetation.

•*trap sediment from running off of the site;* especially, into the lake. Most sediment runoff occurs after necessary existing vegetation has been removed. Once these areas have been disturbed, it is important to cover the soil as quickly as possible. Ways to prevent runoff is by sodding or hydroseeding the exposed/disturbed soil (see Figure 48).

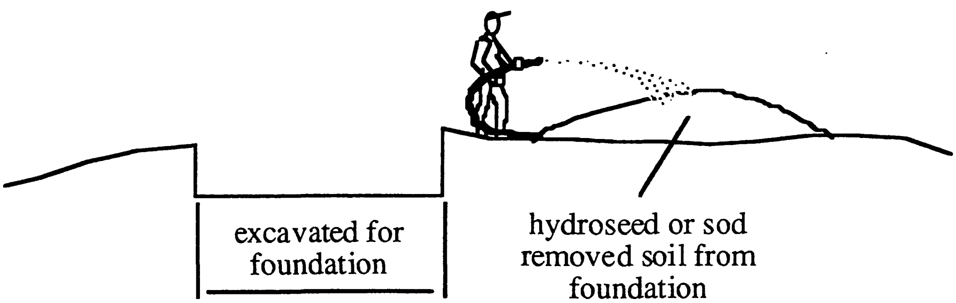


Figure 48: Securing disturbed soils.

• *build traps for remaining sediment runoff which has erosion potential.* It is virtually impossible to eliminate runoff during the construction process; therefore, excess sediment needs to be trapped to prevent possible degradation of the lake's water quality. A simple and relatively inexpensive way to retain the sediment is through the use of stacked hay bales, "silt" fences. Another possibility is re-grading select areas of the site to retain storm water runoff (see Figure 49).

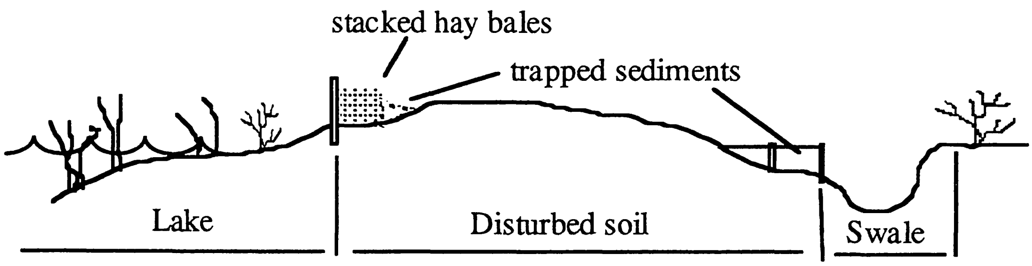


Figure 49: Sediment trapping techniques.

• *plan the above guidelines as part of the construction process.* It is less expensive if done as an active procedure rather than a reactive procedure.

C. Conclusions

The process of preserving a lake environment can be achieved in a variety of ways. The information above documents the steps taken to achieve this goal. It is important to realize that an ecosystem is impacted by biological, social and cultural issues. Therefore, one must study how these issues have impacted the environment in its current state, and predict how they will continue to put pressure on the natural resources that are unique to the inland lake environment.

Visual quality is directly related to the combination of development and the natural setting in which it is located. Through the guidelines presented, individuals as well as groups can provide a standard which will allow development to continue within a natural setting and at the same time, preserve the visual quality of this natural environment.

A relatively new process in the preservation of a natural area experiencing development pressure is known as a conservation easement. A large percentage of those surveyed showed some concern regarding development and its potential effects on the scenery surrounding the lake. Thus, the conservation easement is a valid option in planning for sensitive development. Although land owners may feel that they have little control over the course of future development, an option for individual land owners does exist. One might consider creating a conservation easement with the Leelanau Conservancy. This legal document, which is recorded with the Register of Deeds, can protect an individual's property from the threat of future development; thus providing a framework to protect its natural features from insensitive development. The following measures, which are possible in a conservation easement donation, can help insure preserved environment.

• each easement can be tailored to fulfill the owner's wishes.

• owner still would maintain control over easement; therefore, access is controlled.

• conservancy commitment to monitor and enforce the easement.

• the easement is a permanent part of the title to the land regardless of future ownership.

• does not have to restrict all development.

• benefit to owner from a tax perspective.

The donation of a conservation easement is an option which an individual can exercise to maintain the scenic quality of the landscape. It is highly recommended for those who own large tracts of land; especially along ridges. Not only does this protect the views from uncontrolled development, but it also preserves the plant and animal habitat. In this way, the complete natural "system" might be preserved for future generations, not just fragments of what used to be there. A conservation easement should be considered by land owners who wish to maintain the scenic quality of Lime/Little Traverse Lake.[33]

VI. Organizations and Agencies Protecting Environmental Quality

With the population growth we see in communities surrounding inland lakes, it is apparent that such changes must be anticipated and planned before they cause irreversible damage to the lake.

In many cases an individual can do things to help preserve the quality of the lake by acting responsibly on his or her own property and in use of the lake. There are also times that some type of organized effort is necessary. The presence of a number of groups facilitates this type of action in the Little Traverse-Lime Lake watershed.

Several government agencies already exist which have specific responsibilities for the protection of lake water quality. See Table 18 below. In some cases these agencies can provide avenues to achieve changes or additions to the protective role they play. An individual may find that accomplishing such goals is easier if a group representing many residents can speak to issues that concern them. This is one role organizations such as the Lake Associations or the Leelanau Conservancy might play.

Since lake communities often lie outside an incorporated village or city, the government body closest to the residents is the township. In Michigan townships possess "home-rule" powers giving them control over zoning, building codes and other ordinances. Townships may also provide services such as police and fire protection, waste removal and utility services.[18]

Table 18: Agencies responsible to permit various activities.[39]

Activity	Required Permit	Agency
Build a house	Zoning, land use and/or building permit	Local or county governments
Build a septic system	Septic system permit	District health department
Expose bare earth near water body	Soil Erosion and Sedimentation Control Permit (Act 347)	County or local enforcement agent
Fill, dredge or drain wetlands	Act 203 (wetland) permit	MDNR and some local governments
Dredge, fill, add beach sand or build a permanent dock seawall, or wood barrier in a natural or artificial lake pond, river or stream, including major drains.	Act 346 permit (State Inland Lakes and Streams), Section 10 (Federal Rivers and Harbors Act) and Section 404 (Federal Clean Water Act) permits.	MDNR and/or U.S. Army Corps of Engineers.
Temporary dock (summer season).	No permit required.	
Building in environmental areas, high risk erosion areas, or flood risk areas in close proximity to the shoreline of the Great Lakes or connecting waterway (1000 feet landward of the ordinary high water mark).	State approval in designated areas required except when local government zoning ordinances have been approved by the Water Resources Commission.	
To construct a new dam, reconstruct failed dam, repair, enlarge, alter, abandon, or remove an existing dam.	Permit required from MDNR.	MDNR
To alter or occupy the river channel, streambed, or floodplain. All developments and structures, including bridges and culverts, are subject to the requirements.	Floodplain permits required from MDNR.	MDNR
Major developments	Environmental impact statement. Local governments and citizens may request a state agency to prepare an environmental impact statement on any proposed major action within their jurisdiction that may have a significant impact on the environment or human life.	Council on Environmental Quality
Discharge wastes into lake or stream from a small business or treatment plant.	NPDES	MDNR, Surface Water Quality Division.

Appendix B describes many of the resources one can go to for assistance and information regarding lake management and protection. Each is very briefly described to give a description for what role the organization or agency plays moving from local to State to Federal levels.

APPENDICES

APPENDIX A

HOMEOWNER SURVEY

Lime Lake Users Survey

1. Name (optional) ______________________
2. Address (optional) ______________________
____

3. Please list the number of people present in your home each month of the year.

Jan.____	May ____	Sep.____
Feb.____	Jun.____	Oct.____
Mar.____	Jul.____	Nov.____
Apr.____	Aug.____	Dec.____

4. Which of the following items are in your home? (please circle)

Washing Machine Dishwasher Water Softener Garbage Disposal Water-Saving Devices

5. Please answer the following about your septic system. (please circle)

a) How old is your system? (years).... Less than 5 5-10 10-25 25-50 Over 50 Don't know

b) How old is your drainfield?(years) Less than 5 5-10 10-25 25-50 Over 50 Don't know

c) When was the tank last emptied?.. Within the past year 2-5 5-10 10-20 Over 20 Don't know

d) How often is the tank emptied?.... Yearly 2-4 years 4-8 years 8-15 years Never Don't know

e) How far is the system from the lakeshore? (feet).. less than 25 25-50 50-75 75-100 over 100

6. Where does your drinking water come from (please circle)

Well Spring Lime Lake Bottle or Tank City Water Supply

7. Do you keep a turf lawn? (please circle) YES NO

If YES: a) Do you fertilize your lawn? YES NO

If YES: i) How many times a year do you fertilize? ____

ii) What type (or formula) fertilizer?.............

8. Do you have a buffer of vegetation along the shoreline? (please circle) YES NO

If YES: a) How wide is your buffer strip? (feet)...... Less than 5 5-10 10-20 Over 20

9. Please circle or list the two primary ways you or your family use the lake.

Fishing Water Skiing Motor Boating Ice Fishing Scenic Views

Non-motorized Boating Birdwatching Wildlife Viewing

Other (please list)______________________
____

10. If you have a boat or boats please list the number and type.______________________
____
____

11. Do you feel the amount of boat traffic on the lake is acceptable at the present time?
(please circle) YES NO
If NO please elaborate: ____
____

12. Are you concerned about boat traffic or boat noise becoming a problem in the future?
(please circle) YES NO

13. What types of fish have you caught on the lake in the past year?
____
____

14. Are there fish species you have caught in past years that you no longer are catching on the lake?
(please circle) YES NO

If YES please specify species: ____

15. Are you concerned about the continued development around the lakes?
(please circle) YES NO

If YES please specify what concerns you most about such development. (please check)

"Keyhole" Accesses to the Lake...........................

Increased Number of Boats on the Lake..........

Increased Fishing on the Lake (over Fishing)...

Damage to the Scenic Nature of the Area.......

Degradation of Lake Water Quality...................

Degradation of Plant and Animal Habitat.........

Other (Please Specify) ____
____

16. Are you a member of the Lime Lake Association? (please circle) YES NO

If YES: Are you satisfied with the services provided by the Lake Association?
(please circle) YES NO

20. Do you feel that the necessary information about how you can help to protect your lake is readily available to you?
(please circle) YES NO

If NO: How could information be better provided to you? ______________________________
____
____

Please add any additional comments or concerns about your lake or this survey:
____
____
____

Thank you for taking the time to complete this survey. Your ideas will help us to compile and make available additional resources to all residents in the Lime Lake watershed.

Lime Lake

		# surveys	# respondents	% respondents	Sum		
Survey Response		97	27	28 %			
Question #							
3	Jan		16	59 %	45	Mean for affirmative respondents= 2.81	Mean for all respondents= 1.67
	Feb		14	52 %	32	Mean for affirmative respondents= 2.29	Mean for all respondents= 1.19
	Mar		13	48 %	29	Mean for affirmative respondents= 2.23	Mean for all respondents= 1.07
	April		20	74 %	42	Mean for affirmative respondents= 2.1	Mean for all respondents= 1.56
	May		24	89 %	54	Mean for affirmative respondents= 2.25	Mean for all respondents= 2
	June		26	96 %	67	Mean for affirmative respondents= 2.58	Mean for all respondents= 2.48
	July		26	96 %	88	Mean for affirmative respondents= 3.38	Mean for all respondents= 3.26
	Aug		26	96 %	78	Mean for affirmative respondents= 3	Mean for all respondents= 2.89
	Sept		25	93 %	58	Mean for affirmative respondents= 2.32	Mean for all respondents= 2.15
	Oct		24	89 %	51	Mean for affirmative respondents= 2.13	Mean for all respondents= 1.89
	Nov		17	63 %	35	Mean for affirmative respondents= 2.06	Mean for all respondents= 1.3
	Dec		16	59 %	37	Mean for affirmative respondents= 2.31	Mean for all respondents= 1.37
4	WashMachine		23	85 %			
	Dishwasher		16	59 %			
	Softener		3	11 %			
	Disposal		10	37 %			
	Water Saving Devices		9	33 %			
5a	<5		7	26 %			
	5–10		4	15 %			
	10–25		11	41 %			
	25-50		2	7 %			
	>50		0	0 %			
	Don't know		2	7 %			
5b	<5		7	26 %			
	5–10		4	15 %			
	10–25		11	41 %			
	25-50		2	7 %			
	>50		0	0 %			
	Don't know		2	7 %			
5c	Within Past Year		7	26 %			
	2–5		11	41 %			
	5–10		4	15 %			
	10–20		0	0 %			
	>20		0	0 %			
	Don't know		3	11 %			
5d	Yearly		2	7 %			
	2–4		9	33 %			
	4–8		5	19 %			
	8–15		1	4 %			
	Never		3	11 %			
	Don't know		5	19 %			
5e	<25		0	0 %			
	25–50		0	0 %			
	50–75		5	19 %			
	75-100		2	7 %			
	>100		19	70 %			
6	Well		27	100 %			
	Spring		0	0 %			
	Lake		0	0 %			
	Bottle/tank		0	0 %			
	City		0	0 %			
7	Lawn		13	18 %			

	No Lawn	14	52 %			
7a if yes	Fertilize	8	30 %		62 % of yes #7	
	No Fertilize	5	19 %			
7a (# times)	1	4	15 %			
	2	2	7 %			
	3	1	4 %			
	4	0	0 %			
7a (type)		5	19 %			
8	Vegetation Buffer Strip	13	48 %			
	No Vegetation Buffer	8	30 %			
8 if yes	<5	5	19 %		38% of Yes #8	
	5–10	1	4 %			
	10–20	1	4 %			
	>20	5	19 %			
9	Fishing	17	63 %			
	Water Skiing	6	22 %			
	Motor Boating	14	52 %			
	Ice Fishing	3	11 %			
	Scenic Views	14	52 %			
	Non-motor Boating	8	30 %			
	Birdwatching	1	4 %			
	Wildlife Viewing	6	22 %			
	Other(write-in)	6	19 %			
10	rowboat	5	19 %	11	Mean for affirmative respondents 2.2	Mean for all respondents 0.41
	canoe	6	22 %	7	Mean for affirmative respondents 1.17	Mean for all respondents 0.26
	motorboat	11	41 %	12	Mean for affirmative respondents 1.09	Mean for all respondents 0.44
	pontoon	5	19 %	5	Mean for affirmative respondents 1	Mean for all respondents 0.19
	skiboat	6	22 %	6	Mean for affirmative respondents 1	Mean for all respondents 0.22
	sailboat	6	22 %	6	Mean for affirmative respondents 1	Mean for all respondents 0.22
11	yes	21	78 %			
	no	4	15 %			
11 if no	Comments (text)	3	11 %		75% of No #11	
12	yes	18	67 %		86% of Yes #11	
	no	7	26 %		33% of Yes #11	
13	bluegills	4	15 %		24% of Fishing #9	25 % of affirmative #13
	rockbass	9	33 %		53% of Fishing #9	56 % of affirmative #13
	perch	10	37 %		59% of Fishing #9	63 % of affirmative #13
	smallmouth	12	44 %		71% of Fishing #9	31 % of affirmative #13
	largemouth bass	0	0 %		0% of Fishing #9	0 % of affirmative #13
	brown trout	1	4 %		6% of Fishing #9	6 % of affirmative #13
	rainbow trout	0	0 %		0% of Fishing #9	0 % of affirmative #13
	pike	0	0 %		0% of Fishing #9	0 % of affirmative #13
	Other (text)	10	37 %		24% of Fishing #9	63 % of affirmative #13.
14	yes	5	29 %			
	no	10	59 %			
14 if yes	Species (text)	5	19 %			
15	yes	23	85 %			
	no	2	7 %			
15 if yes	keyhole	18	67 %		78% of Yes #15	
	#boats	12	44 %		52% of Yes #15	
	Over Fishing	5	19 %		22% of Yes #15	
	Damage to Scenery	14	52 %		61% of Yes #15	
	Degraded Water Quality	20	74 %		87% of Yes #15	
	Degraded Habitat	15	56 %		65% of Yes #15	
	Other (text)	3	11 %		13% of Yes #15	
16	yes	19	70 %			
	no	7	26 %			
16 if yes	yes	18	67 %		95 % of yes #16	
	no	0	0 %		0 % of yes #16	
17	yes	17	63 %			
	no	5	19 %			

17 if no	HowBetter? (text)	3	11 %	60 % of no #17

Comments

#7a type	granular, 12/12/12, low phosphate, 12/12/12, organic
#9 other	5 swimming 19%, 1 picnics 4%
#11 if no	1 No large motors, 1 motorboat time periods, ie. skiing 10am-2pm, 1 loud racing boats off lake, 1 jet skiis disturb fishing.
#13 other	6 bass, 1 green bass, 1 trout, 1 undersized brown trout, 1 sunfish, 1 steelhead
#14 if yes	5 brown trout, 2 pike, 1 bluegill
#15 if yes (other)	6 bass, 1 green bass, 1 trout, 1 undersized brown trout, 1 sunfish, 1 steelhead
Final comments	Wants no public swimming access Lake levels Anti rip-rap Fish bigger now than 3 yrs ago Want info on assn. sent to #17 No visible change in water quality since 1955. Dam issue critical to his property & boat use. Set constant water level. Hands off dam. Avoid over use of lake (Higgins/ Coney Island). Need tolerance for boat noise, not just peace & quiet. Dangerous boat traffic, not following regulations. Need education program. Holding tanks; not septic Too much phosphate, septic runoff Annual meeting closer to July 4, when more people there I don't live on lake

Little Traverse Lake

		# surveys	# respondents	% respondents	Sum		
Survey Response		145	84	58 %			
Question #							
#3	Jan		46	55 %	114	Mean for affirmative respondents 2.48	Mean for all respondents 1.36
	Feb		44	52 %	97	Mean for affirmative respondents 2.2	Mean for all respondents 1.15
	Mar		40	48 %	80	Mean for affirmative respondents 2	Mean for all respondents 0.95
	April		48	57 %	103	Mean for affirmative respondents 2.15	Mean for all respondents 1.23
	May		63	75 %	152	Mean for affirmative respondents 2.41	Mean for all respondents 1.81
	June		75	89 %	223	Mean for affirmative respondents 2.97	Mean for all respondents 2.65
	July		78	93 %	304	Mean for affirmative respondents 3.9	Mean for all respondents 3.62
	Aug		79	94 %	294	Mean for affirmative respondents 3.72	Mean for all respondents 3.5
	Sept		68	81 %	166	Mean for affirmative respondents 2.44	Mean for all respondents 1.98
	Oct		63	75 %	141	Mean for affirmative respondents 2.24	Mean for all respondents 1.68
	Nov		49	58 %	104	Mean for affirmative respondents 2.12	Mean for all respondents 1.24
	Dec		50	60 %	136	Mean for affirmative respondents 2.72	Mean for all respondents 1.62
4	WashMachine		65	77 %			
	Dishwasher		42	50 %			
	Softener		23	27 %			
	Disposal		42	50 %			
	SavingDevices		17	20 %			
5a	<5		11	13 %			
	5–10		6	7 %			
	10–25		40	48 %			
	25-50		16	19 %			
	>50		2	2 %			
	Don't know		3	4 %			
5b	<5		11	13 %			
	5–10		8	10 %			
	10–25		40	48 %			
	25-50		14	17 %			
	>50		1	1 %			
	Don't know		3	4 %			
5c	WithinPastYear		28	33 %			
	2–5		35	42 %			
	5–10		5	6 %			
	10–20		0	0 %			
	>20		1	1 %			
	Don't know		5	6 %			
5d	Yearly		11	13 %			
	2–4		37	44 %			
	4–8		14	17 %			
	8–15		3	4 %			
	Never		3	4 %			
	Don't know		5	6 %			
5e	<25		0	0 %			
	25–50		4	5 %			
	50–75		11	13 %			
	75-100		15	18 %			
	>100		48	57 %			
6	Well		74	88 %			
	Spring		4	5 %			
	Lake		0	0 %			

	Bottle/tank	3	4 %		
	City	0	0 %		
7	yes	37	44 %		
	no	44	52 %		
7a if yes	yes	16	19 %	43 % of yes #7	
	no	20	24 %	54 % of yes #7	
7a (# times)	1	9	11 %	56 % of yes #7a	
	2	6	7 %	38 % of yes #7a	
	3	0	0 %	0 % of yes #7a	
	4	2	2 %	13 % of yes #7a	
7a (type)		15	18 %	94 % of yes #7a	
8	yes	56	67 %		
	no	21	25 %		
8 if yes	<5	10	12 %	18 % of yes #8	
	5–10	12	14 %	21 % of yes #8	
	10–20	8	10 %	14 % of yes #8	
	>20	25	30 %	45 % of yes #8	
9	Fishing	41	49 %		
	WaterSkiing	15	18 %		
	MotorBoating	34	40 %		
	IceFishing	4	5 %		
	ScenicViews	49	58 %		
	Non-motor Boating	30	36 %		
	Birdwatching	19	23 %		
	WildlifeViewing	18	21 %		
	Other (text)	26	31 %	25 swimming 30%, 1 ice skating 1%	
10	rowboat	25	30 %	29 Mean for affirmative respondents 1.16	Mean for all respondents 0.35
	canoe	17	20 %	20 Mean for affirmative respondents 1.18	Mean for all respondents 0.24
	motorboat	50	60 %	63 Mean for affirmative respondents 1.26	Mean for all respondents 0.75
	pontoon	0	0 %	0 Mean for affirmative respondents 0	Mean for all respondents 0
	skiboat	17	20 %	19 Mean for affirmative respondents 1.12	Mean for all respondents 0.23
	sailboat	28	33 %	36 Mean for affirmative respondents 1.29	Mean for all respondents 0.43
11	yes	76	90 %		
	no	3	4 %		
11 if no	Comments (text)	2	2 %	67 % of no #11	
12	yes	61	73 %		
	no	15	18 %		
13	bluegills	5	6 %	12 % of fishing #9	12 % of affirmative #13
	rockbass	6	7 %	15 % of fishing #9	15 % of affirmative #13
	perch	33	39 %	80 % of fishing #9	80 % of affirmative #13
	smallmouth	12	14 %	29 % of fishing #9	29 % of affirmative #13
	largemouthbass	1	1 %	2 % of fishing #9	2 % of affirmative #13
	brownTrout	0	0 %	0 % of fishing #9	0 % of affirmative #13
	rainbowTrout	0	0 %	0 % of fishing #9	0 % of affirmative #13
	Pike	10	12 %	24 % of fishing #9	24 % of affirmative #13
	Other (text)	28	33 %	68 % of fishing #9	68 % of affirmative #13
14	yes	24	29 %		
	no	17	20 %		
14 if yes	Species (text)	23	27 %	96 % of yes #14	
15	yes	75	89 %		
	no	5	6 %		
15 if yes	keyhole	67	80 %	89 % of yes #15	
	#boats	53	63 %	71 % of yes #15	
	OverFishing	17	20 %	23 % of yes #15	
	DamageScenic	48	57 %	64 % of yes #15	
	DegradeWaterQual	64	76 %	85 % of yes #15	

	DegradeHabitat	45	54 %	60 % of yes #15
	Other (text)	12	14 %	16 % of yes #15
16	yes	78	93 %	
	no	3	4 %	
16 if yes	yes	69	82 %	88 % of yes #16
	no	2	2 %	3 % of yes #16
17	yes	59	70 %	
	no	16	19 %	
17 if no	HowBetter? (text)	10	12 %	63 % of no #17

Comments

#7a type — granular, 12/12/12, milorganite, 12-12-12 & 23-7-7 weed & Feed, 12/12/2012, scotts, 12/12/12, 30-4-4, ,12/12/12, Scotts turfbuilder

#13 other — 23 bass, 2 sunfish, 1 crappies, 4 bullheads, 2 catfish, 1 trout, 1 dogfish.

#11 if no — Too many big boats, holiday weekends are problem.

#14 if yes — 4 sunfish, 11 bluegill, 5 rockbass, 8 pike, 1 coho, 1 steelhead, 2 perch.

#15 if yes — Development, too many people, increased taxes,
docks too long, jetskis, speedboats too near shore, speeders vs children,
speedboats & jetskis nuisance,
tin homes around lake,
shoreline erosion, water clarity,
wetland development- destroys pike spawning habitat.

#17 if no — Why no septic survey as promised? (testing).
Env. safe products, yard waste, assn. as legal focus.
Need resource list.
Regular newsletter/ info in paper.
Periodic bulletins.
Resource list, newsletters.
I use own common sense concerning the lake.
Nobody asked them to join since 1988.
Need local/ not township board to review house plans.

Final comments
swimmers' itch
Barnacles on boat
high power boats esp in swim areas/ noise
Full timers more important than part timers, who lack stewardship .
Boats too big for lake
jet ski noise
Swimmers itch better
Appreciate assn officers work.
Bad swimmers itch. Big thanks.
Send membership form!!!
Concern about what comes from Lime
Jet ski noise, quality of some domiciles, long piers
beaver dams, creek restrictions, housing density.
No more jetskis.
Jetski noise & traffic
Kids + jetskis = dangerous
Send another questionaire
Holding tank. Want bass stocking.
Vacant lot/ no house.
Keep out salmon, cuts down perch pop
Pleased with stewardship
Against waterfowl removal
Concerned perch habitat
Does assn have legal standing?
Stewardship
Good work!
Keep shoreline natural
Thanks for survey
Stock fish. Resurface Traverse Lake Rd
Should ask type & size septic: tank, drywell, drainfield.
Wants everyone to clean up shoreline after storms.
Against trailers on lake. Faults zoning board, accessor. Lowers prop values.
Poor fishing. Stock fish.
Concerned about marl on lake bottom (?)
DNR never stocked lake in 40 years. Net test is for the birds.
Remove all septics <100' from lake. New setbacks 100' buidings. No fertilizer.
Bill-great!
J. S.'s trash dump leaching into lake. Lack of action frustrating. Thanks to Bill & Mary & other assn offecers.

APPENDIX B

AGENCIES AND ORGANIZATIONS

I. The Lake Association

The group which is most closely linked to the individual lake is the lake association. The lake association acts as the organizing body for the lake community. Typically communities organize to achieve goals that would not be easily accomplished by an individual. Some of these objectives might include:[19]

- environmental protection and improvement
- construction and maintenance of community improvements, parks, refuse clean-up, algal control, etc.
- social and community events such as picnics, holiday celebrations, or other lake activities
- organization and action to gain the cooperation of township, county, state and federal agencies to take needed actions

Thus the lake association can seek to accomplish varied goals as are seen fit by its members. The association also helps to keep the community informed and thus allows for better input from the community. Resources within and outside the community may be discovered and better utilized, be they individuals or organizations willing to contribute time, energy, money or materials.[19]

II. The Leelanau Conservancy

The Leelanau Conservancy was created with several goals in mind. Using private initiative as a driving force, the Conservancy seeks to address problems of land use, water quality, historic preservation, and environmental quality. It has three primary objectives: 1) a land trust and easement program; 2) historic preservation and; 3) environmental stewardship.[31]

III. The Watershed Council

This is a cooperative effort between the four major lake associations, the Leelanau Conservancy and others formed in 1989. The Council has three primary objectives, they are: to establish a long-term water quality data collection program; to establish programs to deal with specific threats to public use of the county's lakes and streams; and to provide educational information though literature, seminars, exhibits and school programs.[34]

The Leelanau Conservancy and the Watershed Council may be contacted at:

105 North First Street

P.O. Box 1007
Leland, MI 49654
(616) 256-9665

IV. County Agencies

A. County Board of Commissioners

This is the governing body of the county. It consists of elected Commissioners from equal population districts within the county.[18]

B. County Planning Department

A citizen group appointed by the Board of Commissioners. The Planning Commission makes policy decisions regarding planning and development within the county. In many counties the professional staff provides specialized planning for townships on a contract basis in addition to their regular county-wide planning.[18]

C. County Road Commission

Plans, builds, and maintains public roads within the county and serving lake communities. Members are appointed by the Board of Commissioners.[18]

D. Environmental Health Department

The Health Department is responsible for the administering of drinking water tests through the State Health Department Lab. They enforce Federal and State water quality standards for public water supplies. Contamination problems of ground and surface water are diagnosed by the Health Department. They also set and issue permits related to construction standards for on-site water well and sewage disposal systems.[33]

E. County Drain Commissioner

This is an elected official responsible for petitions to drain clean water from land areas as specified in the Michigan Drain Code, Act. 40, P.A. 1956. Also responsible for development of drainage districts and management of storm drains.[33]

F. County Sheriff

The Sheriff is an elected official responsible for enforcing laws in unincorporated areas. The Marine division of the Sheriff's department is partially funded by state tax on marine fuel and is responsible for enforcement of the State Boating Control Laws. Other law enforcement officials, including state conservation officers may also enforce the boating control laws.[18]

G. County Board of Public Works

Is responsible for the finance and construction of public works projects as per agreement with the townships, cities, or villages who request and pay for these services.[18]

H. County Board of Parks and Recreation

Plans, develops and maintains public parks within the county.[18]

V. Regional Agencies

A. Northwest Michigan Council of Governments [NWMCOG]

Maintains computer maps and a full Geographic Information System for Northeastern Michigan. They also make available policy information on all aspects of water quality and act as an information center on groundwater protection. Grants are available for specific water quality projects. NWMCOG also make available presentations on inland lake management and groundwater protection.[33]

B. Northwest Michigan Resource Conservation and Development Council Inc.

Assists in grant writing and is responsible for many local watershed projects. The RC&D Council also makes available slide shows on request.[33]

C. Leelanau County Emergency Management

Coordinates the Local Emergency Planning Committee which coordinates mitigation, planning, and response for hazardous material used, stored, and transported or manufactured in the county.[33]

D. Soil Conservation Districts

Promote good conservation practices by individual landowners.

VI. State Agencies and Commissions

A. Michigan Department of Natural Resources [MDNR]

The MDNR is the primary agency for surface water quality issues. A large number of the State environmental laws are administered through the MDNR and various units have expertise in a wide range of areas including municipal and industrial point source pollution to small non-point source planning projects.[33]

The Natural Resources Commission is responsible for policy decisions not decided directly by the State legislature.

A number of divisions within the MDNR have specific responsibilities related to inland lakes. Descriptions of some of these follows:[18]

1. Fisheries Division

Stocking,, lake mapping, habitat studies and improvement, chemical and biological studies, small fishing impoundments, hatcheries and rearing stations, construction of new lakes and rough fish control are major programs of the division. The Institute for Fisheries Research provides a central repository for fish management information and a center for research in fish management. District Fisheries Biologists are provided to local districts.

2. Parks Division

Operates and maintains State Recreation Areas.

3. Law Enforcement Division

Enforces state conservation laws in part by financing state conservation officers stationed throughout the area.

4. Recreation Division

Plans and Coordinates the development of public recreation programs and facilities throughout the state.

5. Geological Survey Division

Carries out studies and enforces the Michigan laws relating to flood plain development, filling and dredging, and lake and river level control.

6. Surface Water Quality Division

The major state-wide water resources planning unit. Carries out short and long range planning functions to maintain, protect, and avoid conflict of interest in Michigan lakes and streams. Studies and makes recommendations to the Water Resources Commission regarding water pollution control in the state.

7. Land and Water Management Division

Develops and maintains public harbors and public access sites. A citizen board, the Michigan Waterways Commission, makes policy decisions that are not made by the legislature.

B. Michigan Water Resources Commission

Delegated by the legislature to enforce water quality standards and to make policy regarding pollution control and other aspects of water management. Any new commercial or industrial of water for waste disposal must obtain a permit from the Water Resources Commission. The Hydrological Survey, Water Development Services, and Water Quality Control Divisions make recommendations to the Commission.[18]

C. Michigan Department of Agriculture

Registers and approves the use of pesticides in the state. It also coordinates the operations of the County Drain Commissioners under the Drain Code of 1956.[18]

D. The Michigan Department of Public Health (Water Supply Division)

Regulates the planning, operation and maintenance of both waste water and water supply treatment plants. A laboratory for the testing of water samples is maintained.[18]

E. Michigan Department of Highways

Builds and maintains state trunk lines. Highway planning is an important function of the Department that may affect lake communities.[18]

F. Cooperative Extension Service

This agency is under the jurisdiction of the Michigan State University Board of Trustees. It provides funds for a County Extension Director, and in some counties additional personnel including planning, 4-H, agriculture, and home economics. These officials, supported by a combination of county, state and federal funds serve as resource people on conservation and the environment.[18]

VII. Federal Agencies

A. Soil Conservation Service

Provides expert advice on the care and maintenance of land to prevent soil erosion and the destruction of valuable land and water resources.[18]

B. Agricultural Stabilization and Conservation Service

Administers a wide range of conservation programs related to agriculture and water quality. Offers cost sharing to farmers installing conservation practices with water quality benefits.[33]

C. United States Department of Defense, Army Corps of Engineers

Maintains district offices. Responsible for the administration of some laws and permits relating to construction in lakes and waterways such as dams or docks. Carries out Civil Works projects to conserve and enhance the desirable qualities of the human and natural environment. All projects are carried out in full compliance with the National Environmental Policy Act (NEPA) and other federal statutes and guidelines for environmental protection.[18]

D. Department of Health and Human Services

Includes Consumer Protection and Environmental Health Service, the Environmental Health Service, the Environmental Control Administration and the National Air Pollution Control Administration.[18]

E. Department of Housing and Urban Development

Operate advisory and assistance programs for communities including funds for open space land acquisition.[18]

F. United States Department of the Interior

Includes a number of agencies with responsibilities related to inland lakes. Some of these include: Geological Survey, Bureau of Reclamation, National Park Service, Fish and Wildlife Service.[18]

1. Sleeping Bear Dunes National Lakeshore

Manages 71,000 acres of land and water, including portions of Leelanau County, for public recreation and resources preservation. Complete groundwater studies for the park have been made and drinking water supplies are regularly treated for public safety.[33]

2. Fish and Wildlife Service

Aids in the conservation of birds, certain mammals and sport and commercial fishes. This includes the application of research findings in the development and management of a system of fish hatcheries; and the acquisition and application of technical knowledge necessary for the perpetuation of fish and wildlife resources.[18]

G. Geological Survey

Primarily a research and data collection bureau which publishes and distributes maps and reports covering the physical features of the United States and its mineral and water resources. Responsibilities include activities in topographic mapping, geology and water resources monitoring.[18]

H. National Oceanic and Atmospheric Administration

Created to help improve comprehension and uses of the physical environment. It is a major environmental management agency and source of information on the effects which human actions may have on environmental quality. Responsible for collecting and disseminating atmospheric data including short and long range weather forecasts and special weather warnings. Operates satellite systems that provide information for weather and flood forecasts and crop conditions. Its data centers provide climate, geophysical, and oceanographic information vital to food supply, construction, energy development, and human health.[56]

I. Environmental Protection Agency

Responsible to coordinate efforts on environmental problems of air and water pollution. Functions include the setting and enforcement of environmental standards, conducting research to examines the effects of specific pollutants on plankton, fish, shellfish, wildlife, plant life, aesthetics, and recreation in any body of water. This includes specific information on the concentration and dispersal of pollutants through biological, physical, and chemical processes as well as the effects of pollutants on biological communities as a whole. Enforces Federal laws relating to water quality. and assists state and local government.[17]

1. EPA Advisory Council on Historic Preservation

An independent federal agency which advises the President, Congress and other Federal agencies on matters regarding protection and preservation of historic properties in the United States.

VIII. Other sources

A. The American Ground Water Trust

(800) 423-7748. Makes comprehensive and scientifically objective ground water information available to industry, government, education, and the pubic. Promotes public education programs and informational activities that will lead to the optimal utilization and protection of America's ground water resources.[1]

APPENDIX C

PLANT DATABASES

Aquatic Macrophytes

Aquatic type refers to the basic form of the macrophyte.

Algae is regarded here as types of algae which are attached to the substrate, are macroscopic, and often appear to take on a look of a higher aquatic plant.

Grass-like / sedge-like are monocots which have linear leaf blades. These plants include the Grass (Graminaceae), Sedge (Cyperaceae), and Rush (Juncaceae) Families.

Other herbaceous refers to any other non-woody annual or perennial plant which dies to the ground at the end of each growing season.

A *woody shrub* is a plant which normally grows with its base in the water, and has living tissue above ground all year.

The categories for growth type have been previously defined— *submergent, free-floating, floating, and emergent.*

May tolerate terrestrial conditions refers to species which can grow on land either temporarily if the water level drops, or in some instances can grow out of water as well as in the water. Many planted have been checked in two or more categories. Certain plants like the Water-plantain (*Alisma plantago-aquatica*) are normally emergent plants, but under certain conditions may be submergent. This plant can also tolerate terrestrial conditions if the water levels drop.

Rooting at water level depth indicates the range of water depth at which the plants are normally found.

Alkalinity is defined under tests and testing. Low, medium and high alkalinity were determined based on criteria defined in Diekelman. These criteria are found in Table 19.

Table 19: Criteria to define low, medium, and high alkalinity.

	Low	Medium	High
pH	6.8 to 7.5	8.0 to 8.8	8.4 to 9.0
Alkalinity	>40 ppm	90 to 150	<150 ppm
Sulfate ion Concentration	>5 ppm	5 to 40 ppm	< 125 ppm

Light requirements (if known) range from *full* sun to mostly shade. Partial sun is about a half day of sunlight.

Growth rates are categorized as slow, medium, or fast. The herbaceous plants are generally considered to be fast growing since they need to grow full size in one growing season. *Potential invasive nuisance* refers to plant species which may dominate if growing conditions favor quick reproduction of the plant.

Flower color and *Blooming time* are entered only for plants with showy or interesting flowers. For many of the plants, literature differed as to the exact blooming time. In many instances where the literature differed the blooming time is approximated .

Other characteristics can be both good and bad. Showy and edible fruit are often characteristics which make these species desirable to plant. Many literature sources have indicated that certain species may *i*nterfere with recreation. Due to the lack of vegetation in Lime and Little Traverse Lakes, it is extremely doubtful that any of these plants would become numerous enough to interfere with recreation without excessive fertilization. Many species of plants cannot tolerate significant amounts of pollution, while others are commonly found in association with pollutants. These plants are indicated with the appropriate checked box. The intolerant plants usually associated with oligotrophic lakes.

Uses refers to reasons why someone would plant them. Because this is a database designed for the homeowner, most of these plants can be used for a buffer strip along the edge of the lakes. Most of the plants are excellent choices to plant along shores, in the water, or in soils with a high degree of erodability. The non-emergent plants in this section of the database are not likely to be planted by the homeowner, since their presence will be determined naturally.

As many residents of Lime and Little Traverse Lakes enjoy watching wildlife, it is important to include what kinds of wildlife are attracted by which plants. The information in this section was interpreted from many different sources.

Propagation categories are included for the homeowner who decides to identify and propagate these plants from the wild, and also for developers who would use native plants in bio-engineering techniques.

Many of these native plants are available at nurseries. Categories include plants common at most nurseries, or plants which could be found at nurseries which specialize in wetland plants. A list of some specialty nurseries will be supplied with the database.

Aquatic Macrophytes Database
Sample Page

Scientific name

Ceratophyllum demersum

Common name

Coontail; Hornwort

☒ Found at Lime / Little Traverse Lake.

Aquatic type

☐ Algae ☐ Grass-like / sedge-like. ☒ Other herbaceous. ☐ Woody shrub.

Growth habit

☒ Submergent. ☐ Free-floating. ☐ Floating. ☐ Emergent. ☐ May tolerate terrestrial conditions.

Rooting at water depth

from 1 feet down to 18 feet.

Alkalinity

☒ Low. ☒ Medium. ☒ High.

Light requirements (floating or emergents)

☐ Full sun. ☐ Partial sun. ☐ Mostly shade.

Growth rate

☐ Slow. ☐ Medium. ☒ Fast. ☐ Potential invasive nuisance.

Flower color (floating or emergents, showy flowers only)

☐ White. ☐ Pink. ☐ Red. ☐ Yellow. ☐ Orange. ☐ Blue. ☐ Purple. ☐ Green or brown.

Blooming time

☐ January. ☐ March. ☐ May. ☒ July. ☒ September. ☐ November.

☐ February. ☐ April. ☐ June. ☒ August. ☐ October. ☐ December.

Other characteristics:

☐ Showy fruit. ☒ Tolerant of pollution and/or turbidity.

☐ Edible fruit. ☐ Intolerant of pollution and/or turbidity.

☒ May interfere with recreation.

Uses

☐ Riparian buffer strip. ☐ Soil/ substrate stabilization.

Wildlife value

☐ Food for fish. ☒ Habitat for invertebrates eaten by fish.

☒ Food for waterfowl. ☒ Habitat for invertebrates eaten by waterfowl.

☐ Food for songbirds. ☒ Habitat for invertebrates eaten by animals.

☐ Food for gamebirds. ☒ Provides shelter / spawning cover for fish.

☒ Food for small mammals. ☐ Nesting & cover for birds / small mammals.

Propogation

☐ Seeds. ☐ Tubers. ☐ Suckering roots. ☐ Rhizomes. ☐ Stolons.

☒ Rooted cuttings. ☒ Transplanting.

Availability

☐ Available at most nurseries. ☒ May be available at specialty nurseries.

Greenbelt /Buffer Plants

Database categories created by the project group are briefly defined below:

The *terrestrial habitat* category is in reference to where the plant will normally occur. If it is usually associated with wet soils, it is categorized as a *lowland plant*. Plants which normally occur in drier soils are classified as *upland plants*. Some plants fit into both categories. The *meadow / field* habitat includes many species that occur in open spaces. Many of the plants observed near the lakes are noted as *found at Lime / Little Traverse Lake*.

Plant types are divided between *woody* and *herbaceous*..

The *woody* plant type categories are broken down to *overstory*, *understory*, *woody vine / groundcover*. Plants such as Balsam Fir (Abies balsamea) may occur in both the overstory canopy, as well as the understory canopy. *Broadleaf* refers to leaves other than needles, while the term *conifer* applies to cone bearing plants that generally bear needles. *Evergreen* plants retain their leaves throughout the year, while *deciduous* do not.

Herbaceous includes all the plants which die to the ground each year (non-woody), as well as to the horsetails. *Grass-like / sedge-like* includes the plants of the Grass (Graminaceae), Sedge (Cyperaceae), and Rush (Juncaceae) families. Ferns and horsetails produce spores rather than flowers and seeds. *Annual* herbaceous groundcovers die completely and emerge from seeds in the spring either. *Perennial* herbaceous groundcovers have roots which stay alive throughout the winter and shoots emerge from the root stock each spring.

Drainage refers to the texture of the soil and not the moisture content. *Well drained* soils normally consist of sands and gravels, although many plants associated with the aquatic environment require that these soils be moist. *Poorly drained* soils are typically clays or silts. Some plants can also *tolerate standing water* for part of the year.

The *pH* of the soil is roughly categorized as *acid*, *neutral*, and *alkaline*. Plants in the *neutral* category are in the range of 6.5 to 7.5.

Under the *growth rate* categories, *potential invasive nuisance* refers to plants that can become prolific if the conditions are optimal for them. These are often introduced exotic species.

The flower color and blooming time are entered for plants with showy or interesting flowers. Many of the literature sources differ as to the exact months of bloom. In these situations, it was approximated as to the correct months.

Other characteristics include *fall color*, *showy fruit*, and *edible fruit*. Some plants were also deemed as *tolerant* or *intolerant to pollution*, mainly atmospheric.

The *uses* categories include *vegetative buffer strips* adjacent to lakes or wetlands. Plants with *sparse visual screening* are not dense enough to block views to the water. *Dense visual screening* will provide a barrier which cannot be seen through easily, and are ideal to block obtrusive views and/or provide privacy. *Soil / substrate stabilization* refers to plants that have the ability to prevent erosion. Some species are better equip to *adapt to disturbed sites*. Plant under the *shade* category can be used as shade trees.

Wildlife values refer to the kinds of wildlife attracted by a plant species.

Propagation methods are those which a homeowner or developer can use to start these plants from the wild. In most cases, some research for additional information will be required by the grower. For example, *seeds* may need a cold stratification period to germinate, or *cuttings* may need to come from a certain age shoot or require a certain rooting hormone to sprout roots.

Many of the plants are *available at local nurseries*. Some of the plants had no information as to their availability and would most likely need to be propagated from the wild. A list of *specialty nurseries* specializing in native or wetland plants will be made available to the Leelanau Conservancy.

Greenbelt/Buffer Zone Plant Database
Sample Page

Scientific name

Acer rubrum

Common name

Red maple; Swamp maple; Scarlet maple

Terrestrial habitat

☒ Lowland. ☒ Upland. ☐ Meadow / field. ☒ Found at Lime / Little Traverse Lake.

Woody plant type

☒ Overstory tree. ☒ Understory tree. ☐ Woody shrub. ☐ Woody vine / groundcover.
☒ Broadleaf. ☐ Conifer. ☐ Evergreen. ☒ Deciduous (loses leaves/needles in winter).

Herbaceous type

☐ Grass-like / sedge-like. ☐ Fern / horsetail.
☐ Annual herbaceous ground cover. ☐ Perennial herbaceous ground cover.

Drainage

☒ Well drained. ☒ Moderately drained. ☒ Poorly drained. ☐ Tolerates wet feet.

pH

☒ Acid. ☒ Neutral. ☐ Alkaline.

Sun / shade preference

☒ Full sun. ☒ Partial sun. ☒ Mostly shade.

Growth rate

☐ Slow. ☒ Medium. ☒ Fast. ☐ Potential invasive nuisance.

Flower color (showy flowers only)

☐ White. ☐ Pink. ☐ Yellow. ☐ Orange. ☒ Red. ☐ Blue. ☐ Purple. ☐ Green or brown.

Blooming time

☐ January. ☐ March. ☐ May. ☐ July. ☐ September. ☐ November.
☐ February. ☒ April. ☐ June. ☐ August. ☐ October. ☐ December.

Other characteristics:

☒ Good fall color. ☐ Showy fruit. ☐ Edible fruit.
☐ Tolerant of pollution. ☐ Intolerant of pollution.

Uses

☐ Riparian /wetland buffer strip. ☐ Sparse visual screening. ☒ Dense visual screening.
☐ Soil/ substrate stabilization. ☒ Disturbed site adaptation. ☒ Shade.

Wildlife value

☐ Food for fish. ☐ Habitat for invertebrates eaten by fish.
☒ Food for waterfowl. ☐ Habitat for invertebrates eaten by waterfowl.
☒ Food for songbirds. ☐ Habitat for invertbrates eaten by animals.
☐ Food for upland gamebirds. ☐ Shelter for fish.
☒ Food for small mammals. ☐ Nesting & cover for birds / small mammals.

Propogation

☒ Seeds. ☐ Tubers. ☐ Suckering roots. ☐ Rhizomes. ☐ Stolons.
☒ Rooted cuttings. ☒ Transplanting.

Availability

☒ Available at most nurseries. ☐ May be available at specialty nurseries.

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