LAKE ASSESSMENT PROGRAM

1989

LITTLE SAND LAKE

(I.D. NO. 29-0150)

HUBBARD COUNTY, MINNESOTA

Minnesota Pollution Control Agency
Division of Water Quality
Program Development Section
Bruce Wilson
April 1990

Commonly used abbreviations in this report include:

1. ug/1 = micrograms per liter = parts per billion

   (These are the traditional units of measurement for phosphorus and chlorophyll (algae) and are the smallest units of measure in this report.)

2. mg/1 = milligrams per liter = parts per million.

   (These are the next largest units of measure and are typically used for alkalinity, nitrogen, total solids and chloride concentrations.)

3. m = meters = 3.3 feet

4. km = kilometer = 3,280 feet (about 0.6 miles)

5. ha = hectare (about 2.5 acres)

6. 1 square mile = 640 acres

7. 1 acre-foot = 1 foot of water over one acre

TABLE OF CONTENTS

SUMMARY AND RECOMMENDATIONS

Little Sand Lake is located near Nevis in Hubbard County. It is a large lake with a surface area of approximately 306 acres. The basin is quite deep with a maximum depth of about 80 feet and has an average depth of about 22.5 feet. The watershed of Little Sand Lake is approximately 19 square miles of which (43 percent) is forested and (46.5 percent) is open water.

The water quality of Little Sand Lake, as measured in 1989, was quite good. Mean total phosphorus averaged 23 ug/l and ranged between 10-43 ug/l. Chlorophyll a concentrations averaged 2.1 ug/l with a maximum of 3.0 ug/l. Secchi transparency averaged 17.4 feet in 1989. All these values fell within a range typical for representative, minimally impacted lakes in the Northern Lakes and Forest ecoregion.

State-of-the-art computer models were used to estimate existing water quality conditions in Little Sand Lake. The models did not reasonably estimate the in-lake conditions observed in 1989. With additional data, however, these models can be used for predicting and diagnosing the water quality of Little Sand Lake, and estimating in-lake conditions based upon changes in land use within the watershed.

Based on the results of the 1989 LAP study, it would be desirable, at a minimum, to maintain existing (1989) conditions. Should improvements in water quality be sought, i.e., a reduction in total phosphorus concentrations, the results of the models used in this study will be useful.

Since the majority of the phosphorus load to the lakes appears to be from the watershed, efforts on improvement should be focused in that area. The following recommendations are based on the 1989 LAP study of the lake:

1. It is important to note that the lake is very sensitive and that relatively minor increases in nutrient loading rates from any watershed sources can degrade the lake. It is essential, therefore, that lake protection efforts be conveyed by all local government groups with land use/zoning authorities for Little Sand Lake and its headwaters. This suggests that the Association should develop a plan for protecting the water quality of the lake. The following could be included in that plan:

   a. The Little Sand Lake Association should continue to participate in the Citizen Lake-Monitoring Program (CLMP). Data from this program provides an excellent basis for assessing long-term and year-to-year variations in algal productivity, i.e., trophic status of the lakes. Measurements should be taken weekly during the summer at the deepest site in each basin, e.g., site 201 as well as secondary site(s). All data should be submitted to the MPCA for permanent storage in the U.S. EPA computer system STORET.

   b. As a good housekeeping practice, the Association should coordinate an evaluation of all on-site septic systems around the lake (if this has not already been completed). Any systems out of compliance with county/state codes should be brought into compliance. These steps may require assistance from Hubbard County. Continue the excellent education program for homeowners around the lake with respect to septic systems, lawn maintenance and shoreline protection. The MPCA, Minnesota Department of Natural Resources (MDNR), and county officials (such as Agricultural Extension agents, and staff from the soil and water conservation district, and Planning and Zoning Office) could provide assistance in this area. The booklet, A Citizens' Guide to Lake Protection may also be a useful educational tool for the Association.

c. Further development in the immediate watershed of the lake should occur in such a manner as to minimize water quality impacts on the lake. Considerations such as setback provisions and septic tank regulations should be strictly followed. MDNR's shoreland regulations will be important in this regard. Also, activities in the total watershed that change drainage patterns, such as wetland removal or major alterations in land use, should be discouraged unless they are carefully planned and adequately controlled.

d. Association members are to be commended for their work in first establishing the Little Sand Lake Association as a viable organization and then playing key roles in developing a county coalition of lake associations (COLA). The existence of a larger group of informed and active citizens will make it easier for Little Sand residents to achieve their own lake protection goals. It is essential that all lake associations in the chain of lakes work closely to coordinate their activities, such as CLMP monitoring, any lake water quality monitoring, determining lake outflow volumes, and Eurasian milfoil prevention measures. An exchange of association newsletters will make it easier to keep up with other associations' efforts.

A critical function of the association will be to begin assembling a list of key decision makers in the watershed. These will be people working at the local government level (such as county commissioners, planning and zoning administrators, extension agents, soil and water conservation district staff) and regional governments. Keep in close contact with these people regarding issues that will affect the chain of lakes and ask to be placed on their mailing lists for issues related to watershed land-use changes. Whenever possible, seek to involve these people in lake activities; invite them to association meetings and other association functions; add them to your newsletter's mailing list.

e. A more detailed examination of possible nutrient sources such as forest management practices, septic systems, lawn fertilizers, road construction and maintenance activities, etc. may aid the Association in determining areas where improvement is needed. Some of the county offices mentioned above may be of help in this regard. The booklets Best Management Practices in Minnesota: Water Quality in Forest Management and Protecting Minnesota's Waters: The Land-Use Connection may be useful in this regard.

2. Although the water quality of Little Sand Lake is good, it could exhibit a measurable decline in transparency with a fairly small increase in in-lake total phosphorus. Changing land-use practices in the watershed provides the greatest likelihood for changes in phosphorus loading. Alternatively, a reduction of the amount of nutrients that enter the lake will continue to assure excellent summer transparency. One means of reducing nutrient input is by implementing best management practices in the watershed (land management activities used to control nonpoint source pollution). Technical assistance may be available through local resource management agencies. MPCA's Clean Water Partnership Program (CWP) is also an option for further assessing and dealing with nonpoint sources of nutrients in the watershed. However, in view of the currently good water quality of Little Sand Lake, an application to the Clean Water Partnership Program may not be warranted at this time.

Things that could indicate the need for a CWP application could include:

a. The development of a lake protection plan for Little Sand Lake, based upon further inspection of land-use practices in the watershed, which indicates a need for major changes (BMPs) to protect the lake from degradation. Major changes are those that could not be addressed through local statutes, county zoning ordinances or services provided by the county soil and water conservation district.

b. Degradation in the water quality of the lake is identified by monitoring of Secchi transparency by CLMP participants. The "degradation" would need to be beyond the year-to-year variability the lake will exhibit naturally. Data included in this report will help to place this in perspective. For example, based on existing data, average summer transparency in Little Sand Lake ranges between about 14 to 17 feet and minimum summer transparency is on the order of 9.5 feet. A reasonable "trigger" level for Little Sand Lake is probably on the order of 12 feet as a summer average and/or a high percentage (>25 percent) of measures below 10 feet during the summer. These numbers can serve as "interim recommendations" until more CLMP data is collected and the trigger levels can be refined.

3. Should a CWP application be deemed necessary, this LAP report will serve as a foundation upon which the further studies and assessments may be based. The water and nutrient income-outgo summaries in this study were estimated based on limited amounts of monitoring data and should be considered best approximations. The next step would be to define water and nutrient sources to the lake in a much more detailed fashion. This should be accomplished prior to implementation of major watershed or in-lake restoration techniques. These detailed studies would allow the estimation of reasonably accurate total phosphorus (and ortho-phosphorus), total nitrogen (and inorganic nitrogen) and water income-outgo summaries. In the absence of these more detailed studies, the report serves as a baseline upon which future changes in water quality of the lake can be measured.

LAKE ASSESSMENT PROGRAM: 1989

Little Sand Lake

(I.D. #29-0150)

INTRODUCTION

Little Sand Lake was sampled by the Minnesota Pollution Control Agency (MPCA) during the summer of 1989 as a part of the Lake Assessment Program (LAP). This program was designed to assist lake associations or municipalities in the collection and analysis of baseline lake water quality data for the purpose of assessing the current trophic status of their lake. The general work plan for LAP includes participation in the Citizen Lake-Monitoring Program (CLMP), examination of land use and drainage patterns in the watershed of the lake and an assessment of the data collected. The study was initiated at the request of the Little Sand Lake Association (Association). The Association was concerned about the cumulative impacts of intensive lakeshore development upon the lake's water quality.

Little Sand Lake was sampled on four occasions during the spring and summer of 1989. Bruce Paakh from the Detroit Lake's Regional Office conducted the majority of the sampling in cooperation with the Association. CLMP measurements were collected by Mel Luke, Charles Alberg and Robert Shotwell during the summer of 1989. Land-use information for the lake's watershed was assembled by the Hubbard County Soil and Water Conservation District by William Alden.

A history of Little Sand Lake and the surrounding area was assembled by Pat Albert and is included in the Appendix of this report. A brief summary of the history of this area is as follows:

1890s	-	First significant land purchase from U.S. Government by August Welge. Saw mill located on Lake Ida for area logging operations.
1910-1925	-	Dry years. Dam constructed below Little Sand Lake was blown up. Increasing amounts of land plotted. Five resorts on lake. Horse and buggy "Blueberry Special" picks up guests at Dorset from Great Northern Railroad Station.
1928	-	Chateau Paulette established.
1930s	-	Drought years.
1949	-	County Road 7 was paved.
1940s & 1950s	-	Some resort development, one resort converted to a camp and cabins built.

1987 - Monitoring of transparency of Little Sand Lake is initiated through CLMP.

1988 - Intensified efforts by lake association to protect the lake. Little Sand Lake Association submits an application to MPCA for inclusion in the Lake Assessment Program.

1989 - Lake Assessment Program study conducted.

BACKGROUND

Little Sand Lake is located about 2 miles northeast of Dorset in Hubbard County (Figure 1). The lake has a surface area of approximately 386 acres and based on size, it would rank in the upper 10 percent of lakes in Minnesota. It has a maximum depth of approximately 80 feet, which is quite deep for lakes in northern Minnesota. Little Sand Lake has one basin (Figure 2).

There are seven lakes immediately upstream of Little Sand Lake including Big Mantrap, Upper Bottle, Lower Bottle, Big Sand, Ida and Gilmore Lakes. These lakes are relatively large and tend to be quite deep with a maximum depth of 135 feet noted in Big Sand Lake (Table 1).

Little Sand Lake was formed in the pitted to hilly moraine deposits of the Wadena lobe of the late Wisconsin glaciation. Soils of this area are classified as Menahga-Marquette. These soils are light-colored formed from non-calcareous fine to medium outwash sands. The area is heavily forested with jack pine, aspen and birch.

As land use affects water quality, it can be useful to divide the state into regions where the land use and water resources are similar. For Minnesota, this results in seven regions, referred to as "ecoregions," as defined by soils, land surface form, natural vegetation and current land use. Little Sand Lake is located in the Northern Lakes and Forests ecoregion (Figure 1).

Little Sand Lake is a part of the Mantrap Valley Watershed (which is part of the Crow Wing Watershed). The watershed of Little Sand Lake is approximately 12,128 acres (19 square miles), of which the lakes comprise about 47 percent. The ratio of the total watershed to lake surface ratio is approximately 30:1. Land use in the watershed is dominated by forested and water land uses (Table 3), which is quite typical for this region.

In this portion of Minnesota, average annual precipitation ranges between 26-28 inches and evaporation ranges between 30-32 inches (Gunard, 1985). Annual average run-off is approximately five inches. One-in-ten years low and high run-off is approximately one inch and eight inches, respectively. The springtime ice-out has usually occurred by April 20.

RESULTS AND DISCUSSION

Water quality data was collected on May 13, July 7, August 22, and September 13, 1989, at two sites on Little Sand Lake (Figure 2). Site 101 was located at the site with the greater depth (middle of the main part of the lake) and Site 102 was located in the north arm of the lake that has a depth of about 40 feet. Lake surface samples were collected with an integrated sampler, which is a PVC tube 6.6 feet (2 meters) in length and an inside diameter of 1.4 inches (3.5 centimeters). Mid-depth and near-bottom samples were collected with either a two-liter PVC Kemmerer or Van Dorn sampler.

Sampling procedures were employed as described in the MPCA Quality Control Manual. Laboratory analyses were performed by the laboratory of the Minnesota Department of Health using U.S. Environmental Protection Agency approved methods. Samples were analyzed for nutrients, color, solids, pH, alkalinity, turbidity, conductivity, chloride, and chlorophyll (Table 4). Temperature and dissolved oxygen profiles and Secchi disk transparency measurements were also taken. CLMP Secchi disk measurements from 1987, 1988, and 1989 were also available for comparison. All data was stored in STORET, the United States Environmental Protection Agency's (EPA) national water quality data bank. The following discussion assumes that the reader is familiar with basic water quality terminology as used in the "Citizens' Guide to Lake Protection."

In-lake Conditions: 1989

Dissolved oxygen and temperature measurements, obtained at one meter intervals from the surface to the bottom were taken at site 102 in the northern arm and at midlake site 101. Similar patterns were observed at both sites.

Graphic depiction of the data are called profiles because they allow examination of conditions by depth. The dissolved oxygen and temperature profiles indicated well mixed conditions on May 30, 1989 (Figure 3a). That is, the lake was relatively similar from top to bottom which is typical for spring conditions in Minnesota. As the season progresses, the surface waters warm and become less dense (e.g. warm water stays on the lake top). Accordingly, the warmer surface waters are separated from the colder bottom waters by a zone of transition called the thermocline. Lakes that are sufficiently deep (e.g.

greater than about 35-40 feet) may be generally expected to be stratified by temperature layers as described above. These lakes are called dimictic lakes (that is, they are completely mixed in the spring and again in the fall). Little Sand Lake is a dimictic lake.

By the July 13, 1989, sampling period, the lake had stratified into three layers: (1) the well-mixed surface waters extended to a depth of about 18 feet; (2) the zone of transition from 18-36 feet; and (3) the bottom waters below this range (Figure 3b). Oxygen concentrations remained about 8 mg/l (milligrams per liter or parts per million) in the surface zone and increased somewhat in the thermocline. The increase of oxygen in thermocline was likely due to algal photosynthesis (which produces oxygen) at these depths. Oxygen concentrations quickly declined in the bottom zone from about 6 mg/l to less than 1.0 mg/l on this date. Oxygen concentrations continued to decline over the summer in the bottom zone to about .0 mg/l. This reduction in oxygen is a reflection of the oxygen demand of the sediments and calm conditions, which do not allow for a downward mixing of oxygen into the lower layer. A level of 5 mg/l or greater is generally considered necessary for long-term game fish survival. Fall mixing began by mid-September as evidenced by the cooler water temperatures and the increased oxygen in the bottom waters.

Dissolved oxygen concentrations in the hypolimnion were well below 5 mg/l on most dates. This reduction of oxygen in the hypolimnion indicates that the sediments of the lake exert a significant oxygen demand on the water as is typical. The oxygen is depleted as it is used in the decomposition of organic matter in the sediments. Its effects are most pronounced during periods of stratification (e.g. summer and winter) when there is little or no oxygen produced in the hypolimnion. This is a common occurrence in Minnesota lakes.

Using all of the data, total phosphorus (TP) concentrations (an important nutrient for plant growth) averaged approximately 23 ug/l (micrograms per liter or parts per billion) in the epilimnion (Table 4) during the summer of 1989. This value is on the upper range of concentrations found in a set of representative - minimally impacted lakes in the Northern Lakes and Forests ecoregion (Table 4). Summer epilimnetic phosphorus concentrations in Little Sand Lake generally ranged between 10-23 ug/l. However, while most of the values ranged from 10-23 ug/l, two extremely anamologous values of 46 and 43 ug/l were noted on July 13, 1989 (for sites 101 and 102). These values are extremely high and are not corroborated by concurrent measured parameters. It should be noted that the previous two days had severe thunderstorm activity with large hail. However, it could also be that there could be sampling contamination, laboratory contamination, as well as general variability. These two elevated values are not believed to be representative of the lake. Future monitoring efforts should employ appropriate field and laboratory procedures to reliably measure 10-15 ug/l of total phosphorous.

Hypolimnetic phosphorus concentrations may become elevated if the hypolimnion becomes anoxic (losses of oxygen). Under these conditions, phosphorus, which is normally bound to iron or other elements in the sediments, may be released into the water just above the sediments. Although phosphorus is effectively trapped in the hypolimnion under stratified summer conditions, it will be mixed into the water column when stratification breaks down (due to cooling of the water and wind mixing) in the fall.

Total nitrogen (TN) concentration, which consists of total Kjeldahl nitrogen plus nitrate and nitrate-N, averaged 0.390 mg/l over the summer. This concentration is very typical for this region. Nitrite and nitrate-N concentrations were less than 0.01 mg/l which is also expected for lakes in this region.

The ratio of TN:TP can give an indication as to which nutrient is limiting the production of algae in the lake. For Little Sand Lake, the TN:TP ratio is 21:1. This suggests that phosphorus is the limiting nutrient in Little Sand Lake. Generally, phosphorus is the least abundant nutrient and, therefore, is the limiting nutrient for biological productivity in a lake. The TN:TP ratio is somewhat lower than found in minimally impacted lakes in this region.

Chlorophyll a concentrations provide an estimate of the amount of algal production in a lake. During the summer of 1989, chlorophyll a concentrations ranged from 1.1 ug/l to 3.0 ug/l with an average of 2.2 ug/l. Concentrations from 10-20 ug/l would be perceived as a mild algal bloom, while concentrations greater than 30 ug/l would be perceived as a severe nuisance (Heiskary and Walker, 1988). Both the average and maximum chlorophyll a concentrations for Little Sand Lake are substantially lower than the typical values for this region. Secchi disk transparency is generally a function of the amount of algae in the water. Suspended sediments or color due to dissolved organics may also reduce water transparency. Color, as measured at site 101, averaged 6 Pt-Co Units indicating low coloration. Total suspended solids averaged 1.8 mg/l over the summer. The total suspended solids value is typical for this region and may be influenced by summer storms and motor boat activities. These levels of color and total suspended solids will tend to limit water transparency in Little Sand Lake. Secchi disk transparency ranged from 11 to 27 feet (3.3 to 8.3 m) and averaged 17.4 feet (5.3 m) during the summer of 1989. These transparency measures are greater than the typical range for minimally impacted lakes in the Northern Lakes and Forests ecoregion.

Along with the CLMP transparency measurements subjective measures of Little Sand Lake's "physical appearance" and "recreational suitability" were made by the CLMP observers. (Figure 4). Physical appearance ratings range from "crystal clear" (Class 1)... to "dense algal blooms, odor, etc." (Class 5) and recreational suitability ratings range from "beautiful, could not be any nicer" (Class 1)... to "no recreation possible" (Class 5) in this rating system (Heiskary and Wilson, 1988). Transparency, and recreational suitability for 1989 are presented in Figure 4.

The recreational suitability as "beautiful, could not be any nicer" (Class 1) for almost all of the summer. Site 201 was rated likewise until the rating changed to occasionally "very minor aesthetic problems, excellent for swimming..." (Class 2) in July and August. Secchi transparency tended to decline from mid-July to September, going from about 25 feet to a minimum of 12 feet by the end of summer.

The other water quality parameters such as conductivity, turbidity and alkalinity are fairly typical for lakes in the region. The alkalinity and conductivity indicate that Little Sand Lake would be considered a moderately hard water lake.

One means to evaluate the trophic status of a lake and to interpret the relationship between total phosphorus, chlorophyll a and Secchi disk readings is Carlson's Trophic State Index (TSI, Carlson 1977). This index was developed from the interrelationships of summer Secchi disk transparency and the concentrations of surface water chlorophyll a and total phosphorus. TSI values are calculated as follows:

Total phosphorus TSI (TSIP) = 14.42 ln (TP) + 4.15

Chlorophyll a TSI (TSIC) = 9.81 ln (chl a) + 30.6

Secchi disk TSI (TSIS) = 60 - 14.41 ln (SD)

TP and chlorophyll a are in ug/l and Secchi disk transparency is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of 10 units represents a doubling of algal biomass.

Average values for trophic variables in Little Sand Lake and respective TSI's are presented in Table 4 and Figure 5. Based on these values, Little Sand Lake would be considered mesotrophic in condition. The mean TSI of 41 would rank Little Sand Lake at the 75th percentile relative to 800 other lakes in the Northern Lakes and Forests ecoregion. In other words, its TSI value is lower than (less eutrophic) 75 percent of the lakes we have assessed in this region. The individual TSI values for chlorophyll and transparency agree quite well. In contrast, the phosphorus values measured in the lake suggest that in-lake conditions could be considerably worse than measured by chlorophyll and transparency. Average phosphorus values were strongly affected by relatively high concentrations measured on July 13 (e.g. 43-46 mg/l versus 10-19 mg/l otherwise noted for this lake). If these two sample values were excluded, corresponding TSI values for phosphorus would be in much closer agreement with measured chlorophyll and Secchi values.

Another means for comparing these three variables is graphically depicted in "scatterplots" seen on Figure 6. These scatterplots are average summer data from Minnesota lakes displayed for (a) chlorophyll-total phosphorus values, (b) Secchi-chlorophyll values, and (c) Secchi-total phosphorus. As may be observed, the relationships for Little Sand Lake do not appear to strongly deviate from general relationships observed across Minnesota.

Another, and perhaps better, means for assessing trends in water quality is by examining Secchi transparency data collected over a number of years. Secchi transparency measurements collected on a routine basis over a number of years can provide a good base for evaluating year-to-year fluctuations in water quality and can be used to assess long-term trends in water quality. Summer mean Secchi transparency for Little Sand Lake, including both MPCA and CLMP measures, is presented in Figure 4.

Mean summer transparency appears to be substantially greater in 1989 (x = 17.4 feet +/- 1.1 feet than in 1988 and 1987 (14.1 +/- 0.5 feet and 13.8 +/- 0.7 feet, respectively). These average summer transparency values are quite comparable to values measured in upstream lakes (Table 2). Values varied from about 10.8 feet (3.3 m) in Ida Lake to 15.1 feet (4.0 m) in Big Sand Lake.

Many factors, such as the amount of rainfall and runoff, can cause the year-to-year changes in transparency. This year-to-year variation in transparency should not be mistaken as an indication of long-term trends. Continued and consistent participation in CLMP will help to identify long-term changes in the water quality of Little Sand Lake.

Water Level Fluctuations

The Minnesota Department of Natural Resources (MDNR), in conjunction with local citizens operate a volunteer lake level monitoring program. Lake level data for the time periods 1972 - 1979 and 1988-1989 have been recorded by the MDNR and are summarized in the Appendix. In general, the average water level elevation is 1427.6 +/- about 0.5 to 1.3 feet over the summer.

MODELING SUMMARY

Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in the lake. Alternatively, they may also be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the amount of water that enters the lake. To analyze the 1989 quality of Little Sand Lake, the models of Reckhow and Simpson (1980) and MINLEAP (Wilson, 1988) were used. Reckhow and Simpson's model is used extensively for assessing lake water quality. A more recently developed model, the "Minnesota Lake Eutrophication Analysis Procedure," (MINLEAP), was also used. This model was developed by MPCA staff based on an analysis of data collected from a set of representative minimally impacted lakes for each ecoregion. It is intended to be used as a screening tool for estimating lake condition with minimal input data and is described in greater detail in Wilson and Walker (1989).

No actual measure of water flow into or out of the lake or measures of nutrient concentrations into or out of the lake were made. Rather, published runoff coefficients, precipitation and evaporation data, and nutrient export coefficients were used in this modeling. Precipitation and evaporation data were derived from Gunnard (1985) and preliminary data from the State Climatology Office (1989).

The MINLEAP model was developed from analysis of lake, watershed and regional characteristics of minimally impacted representative lakes. The watershed of Little Sand is substantially different than those lakes of the model because it has so many large upstream lakes which account for about 55 percent of the watershed. This is of significance because these lakes act as buffers for Little Sand Lake by serving as nutrient and sediment traps. Therefore, it is likely that the water quality reaching Little Sand is much better than estimated in the MINLEAP model.

Accordingly, the results from the MINLEAP modeling are presented in Table 5, where it may be observed that the predicted phosphorus concentration (27 ug/l) is slightly greater than the observed concentration of 23 ug/l. However, the predicted chlorophyll (algae) and transparency were significantly worse than observed in 1989. For example, the model predicted (1) about 8 ug/l of chlorophyll versus the 2.2 ug/l that was measured and (2) an average summer transparency on the order of 2.3 m (about 7.5 feet) versus the measured average summer transparency of 5.3 m (about 17.4 feet at Site 201).

Based on MINLEAP calculations, the estimated water residence time is on the order of about 0.9 years (average time it would take to replace the entire volume of the lake). Little Sand Lake retains approximately 50 percent of the phosphorus that enters the lake, based on the water and phosphorus characteristics used in the model. Overall, MINLEAP results indicate that conditions measured in Little Sand Lake in 1989 are better than expected based on the lake's size and depth, watershed size and regional average stream water quality.

The second level of modeling employs the methods of Reckhov and Simpson (1981). For this effort, average precipitation, evaporation and runoff coefficients for the region were used. The end product of this modeling is the estimation of in-lake water quality based on typical land-use impacts. While the results of the Reckhov-Simpson modeling are very general in nature, they do allow a comparison of nutrient sources by land use category. The majority of phosphorus calculated by this method to reach the lake was estimated to be the result of runoff from about 5220 acres of forested areas (e.g. 317 kg P/year, see Table 6). This amount, while a large portion of the total load to the lake from all sources, is not going to get much lower (e.g. forests hold on to phosphorus quite efficiently in general). For example, the amount of phosphorus from forested areas may be expected to be about 10 to 20 percent of what may be generated from residential/urban areas. In contrast, as may be seen in Table 6, the estimated phosphorus generated by the residential/urban land-use area of about 313 acres, was 160 kg P/year. The estimated phosphorus load from septic tanks around the lake was estimated to range from a low value of 20 kg P/year to a high value of 80 kg P/year with a most-likely value of approximately 50 kg P/year. While these estimates are crude approximations of what may be actually occurring, they do indicate that septic tanks can be a relatively important source of phosphorus to the lake (e.g. contribute about 5-8 percent of the total load), particularly if there are old improperly maintained systems. This is particularly relevant given that lakeshore development has increased from 33 to 166 homes/cabins in just 22 years.

The Reckhow-Simpson approach to predicting the lake's conditions provided estimates of lake conditions quite similar to MINLEAP with estimated low, most-likely and high phosphorus concentrations of 14, 20 and 28 ug/l, respectively. The calculated amount of phosphorus reaching the lake from all sources was estimated to range from 447 to 879 kg P/year, with a most-likely value of 663 kg P/year.

Goal Setting

The water quality observed in Little Sand Lake in 1989 was in some respects worse than would be predicted and in some aspects much better. The anomaly principally relates to the uncertainty associated with phosphorus measurements, as previously described.

First, let's focus on the phosphorus quantities measured in the lake. The levels that are typical for this lake are less than 25 ug/l, which are extremely low levels for the typical sampling and analytical laboratory procedures. Future monitoring must employ suitable laboratory and field methods to reliably measure 10-15 ug/l of total phosphorus. There is evidence that sample contamination occurred on at least one occasion in the sampling of Little Sand Lake. Therefore, it is reasonable to assume that the sample results may be biased (or may have been contaminated and therefore influence the summary statistics).

Corroborating evidence for this may be observed in table below. Based on measurements from lakes across Minnesota, relationships have been developed that allow estimates of algae based on the amount of the most important aquatic plant growth nutrient phosphorus. From these analyses it would be expected that 23 ug/l of phosphorus would generate an average of about 6.4 ug/l of algae, which would in turn correspond to about 2.6 m (8.5 feet) of average summer transparency. However, measured average summer values for chlorophyll (2.2 ug/l) and Secchi (5.3 m) correspond nicely to values that would be expected for 10 ug/l of total phosphorus (not 23 ug/l total phosphorus). It should be noted that there may be other causes of deviations from expected phosphorus-chlorophyll relationships other than laboratory/field contaminations and variability. There may be a combination of factors such as:
(1) zooplankton grazing of the algae, which may not dependable for year-to-year control of algae; (2) periodic limitation by other nutrients such as nitrogen; or (3) shortage of other growth limiting factors such as trace elements.

Typical relationships between average summer total phosphorus, chlorophyll-a and Secchi transparency along with 1989 values from Little Sand Lake.

Total Phosphorus ug/l	Chlorophyll-a ug/l	Secchi Depth m (feet)
10	1.9	5.3 (17.4)
20	5.2	2.9 (9.5)
23*	6.4*	2.6* (8.5)*
30	9.5	2.1 (6.9)
40	14.4	1.6 (5.2)
1989 Measured Values		
23	2.2	5.3 (17.4)
	1987-88 Mean Secchi	4.3 (14.1)

* Estimated algae and transparency based on the total phosphorus concentration of 23 ug/l.

Regardless of the causes of the discrepancy, it should be apparent that the lake will be exceptionally sensitive to additions of nutrients to its waters from any source. This means that if additional phosphorus loading occurs, the lake will be very susceptible to rapid degradation as measured by the amounts of algae or the degree of transparency. Developments occurring in the lake's immediate watershed offer the greatest likelihood of causing immediate and perceptible degradation. Lakeshore development (e.g. areas reasonably close to the lake) may impact the lake because nutrients from these sources will tend to get directly into the lake and the phosphorus from urban/residential sources is relatively potent in terms of its impacts upon algae and aquatic plants (some call "weeds"). Developments further from the lake may also have direct impacts as well.

Continued Secchi transparency monitoring of Little Sand Lake will be an important part of an overall strategy for protecting the water quality of the lake. One of the best and least expensive means will be through the CLMP. Secchi transparency should be monitored weekly during the summer. This monitoring should be conducted each summer. At a minimum, five consecutive summers of transparency monitoring are recommended for a statistically valid trend assessment. This data will provide a basis for separating year-to-year variation in water quality from long-term changes in the quality of Little Sand Lake.

Lake protection for Little Sand Lake may include the following objectives:

(1) Based on the results of this study and the perceptions of CLMP observers, it would be desirable to maintain existing (1987-89) conditions;

(2) Maintain average summer transparency as measured at site 201 of at least 4.2 m (13.9 feet). To put this in perspective, the minimum transparency value noted since 1987 has been about 9.5 feet. If instantaneous transparency values fall below 9.5 feet, and particularly on several occasions, then this is evidence that lake degradation may be occurring and that further examinations are warranted.

(3) In-lake phosphorus should remain below 15-20 ug/l as a summer average.

REFERENCES

A Citizens' Guide to Lake Protection. 1985. Minnesota Pollution Control Agency, St. Paul, Minnesota and Freshwater Society, Navarre, Minnesota. 16 pages.

Arneman, H.F. 1963. Soils of Minnesota. University of Minnesota, Agricultural Extension Service and U.S. Department of Agriculture.

Borchert, J.R., G. W. Orning, J. Stinchfield, and L. Maki. 1970. Minnesota's Lakeshore: resources, development, policy needs. Summary of the Minnesota Lakeshore Development Study, University of Minnesota, Department of Geog. and C.U.R.A., Minneapolis, Minnesota.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography 22: 361-369.

Gunard, L. 1985. U.S. Geological Survey. Water Supply Paper 2300. U.S.G.S. 702 Post Office Building, St. Paul, Minnesota.

Heiskary, S.A. and W.W. Walker. 1988. Developing phosphorus criteria for Minnesota lakes. Lake Reservoir Management. 4(1):1-10.

Heiskary, S.A. and C. B. Wilson. 1988. Minnesota Lake Water Quality Assessment. Minnesota Pollution Control Agency, St. Paul, Minnesota.

Minnesota Department of Natural Resources. 1968. An Inventory of Minnesota Lakes: Bulletin 25. MDNR, St. Paul, Minnesota.

North American Lake Management Society. 1988. Lake and Reservoir Restoration. Guidance Manual. Developed for Office of Res. and Dev.-Corvallis ERL and for Office of Water Criteria and Standards Div. Nonpoint Source Branch.

Prairie, Y.T. and J. Kalff. 1986. Effect of catchment size on phosphorus export. Water Resource Bulletin 22(3):465-470.

Reckhow, K.H., and J.T. Simpson. 1980. A procedure using modeling and error analysis for the prediction of the lake phosphorus concentration from land use information. Can. J. fish Aquat Sci. 37:1439-1448.

Reckhow, K.H. and S.C. Chapra. 1983. Engineering approaches for lake management. Volume 1: Data analysis and empirical modeling. Butterworth Publishers. U.S. EPA.

State Climatology Office. 1989. Unpublished map of hydrologic year Precipitation. Oct. 1987 - Sept. 1988. MDNR Div. of Waters.

Verry, E.S. and D.R. Timmons. 1982. Waterborne nutrient flow through an upland-peatland watershed in Minnesota. Ecology 63 (5): 1456-1467.

Walker, W.W., Jr. 1986. Empirical methods for predicting eutrophication in impoundments; Report 4, Phase III: Applications Manual Technical Report E-18-9 prepared by W.W. Walker Hr. Env. Engr. Concord Mass. for U.S. ACE Waterways Experiment Station Vicksburg, Mississippi.

Walker, W.W., Jr. 1985. Urban nonpoint source impacts on a surface water supply. Pages 129-137. Perspectives on Nonpoint Source Pollution. Proceedings of a national conference. Kansas City, Missouri, May 19-22, 1985. U.S. EPA 440/5-85-01.

Wilson, C.B. 1988. Lake water quality modeling used in Minnesota. Presented at National Conference on enhancing State Lake Management Program. May 12-13, 1988. Chicago, Illinois.

Wilson, C.B. and W.W. Walker Jr. 1989. Development of lake assessment methods based upon the aquatic ecoregion concept. Lake and Reservoir Manage. 5(2):11-22.

TABLE 1. LAKES IN THE WATERSHED OF LITTLE SAND LAKES

Lake Depth		Surface Area(Acres)	Maximum
BIG MANTRAP		1,770	68
UPPER BOTTLE	465	55	
LOWER BOTTLE	660	110	
BIG SAND	1,640	135	
IDA		76	40
GILMORE	91	54	

Total Area = 4,702 acres

= 7.3 square miles

TABLE 2. SECCHI SUMMARY FOR LAKES IN THE WATERSHED OF LITTLE SAND LAKE

(Summary data for time period 1985-1990)

Lake/Site	Area (acres)	SD(m)		Numbe Observations
BIG MANTRAP				
29-0151-01 (East Basin)	750	3.2	10.5 feet	4
29-0151-05 (Home Bay)	80	4.8	15.7 feet	4
29-0151-02 (Middle Basin)	700	33.2	10.5 feet	8
29-0151-04 (West Arm)	200	4.0	13.1 feet	4
UPPER BOTTLE				
29-0148	465	3.5	11.5 feet	19
LOWER BOTTLE				
29-0180	660	4.0	13.1 feet	12
Max depth = 110′				
BIG SAND Max depth = 135′	1640	4.6	15.1 feet	53
Ida Lake	76	3.3	10.8 feet	19
Gilmore Lake	91	4.0	13.1 feet	11
Little Sand	386	4.7	15/4 feet	39

TABLE 3. LITTLE SAND LAKE: MORPHOMETRIC, WATERSHED, AND FISHERY CHARACTERISTICS

MDNR I.D. # 29-0150

Area[1]: 386 acres (156 ha)

Mean Depth: 22.5 feet (6.9 m)

Maximum Depth: 80 feet (24.4 m)

Volume: 8923 acre-ft (11.0 Hm3 or million cubic meters)

Littoral Area: 39%

Watershed Area2: 12,128 acres (4,910 ha)
19 mi^2 (49.1 Km2)

Watershed Area: Lake surface area ratio: 30:1

Estimated Average Water Residence Time = 0.9 years

Fisheries-Ecological Classification: Walleye-Centrarchid
Management Classification: Centrarchid-Walleye

Public Access: 1
Inlets: 1 Outlets: 1

Land Use (percentage):

	Forest	Water & Marsh	Pasture	Cultivated	Urban-Residential
Little Sand Lake2	43	54.1	0.2	--	2.6
Area (acres)	5220	6565	30	--	313
Northern Lakes & Forests3	50-80%	15-30%	0-6%	< 1%	0-7%

Shoreland Zoning: Recreational Development4

Development (Homes)	Seasonal	Permanent	Total
1967	26	7	33
1982	56	10	66
1989	133	33	166

1. Planimetered from MDNR bathymetric map.
2. Estimated by Hubbard County Soil & Water Conservation District (Alden, 1989)
3. Percent of 40-acre parcels with land use characteristic (Land Management Information Center, 1986).
4. Survey results from MDNR fisheries surveys.

TABLE 4. AVERAGE SUMMER WATER QUALITY AND TROPHIC STATUS INDICATORS. Based on surface water data from 1989.

LITTLE SAND LAKE

Parameter	mean	Typical Range for Ecoregion1
Total Phosphorus (ug/l)	23	14-27
Chlorophyll-a (ug/l) mean	2.2	<10
Chlorophyll-a maximum	3.0	<15
Secchi disk (feet)	17.4	8-15
Total Kjeldahl Nitrogen (mg/l)	0.380	<0.75
Nitrite + Nitrate-N (mg/l)	<.01	<0.01
Alkalinity (mg/l)	180	40-140
Color (Pt-Co Units)	55	-
pH (SU)	8.7	7.2-8.3
Chloride (mg/l)	2.2	<2
Total Suspended Solids (mg/l)	1.8	<2
Total Suspended Inorganic Solids (mg/l)	1.0	<2
Turbidity (NTU)	1.0	<2
TN:TP ratio	21:1	25:1 - 35:1

Trophic Status Indicators: 1989

Carlson Trophic State Index Values		Percentile2
TP TSIP	49.	--
Chl-a TSIC	38.	--
Secchi TSIS	36.	--
Mean TSI	41.	75

1. 25-75th percentile for representation - minimally impacted lakes in Northern Lakes and Forests (Heiskary and Wilson, 1988).

2. Relative to approximately 800 other lakes in Northern Lakes and Forests ecoregion. 100 percent level implies lowest TP concentration or deepest Secchi disk measurement for that ecoregion.

TABLE 3. MINLEAP MODEL RESULTS FOR LITTLE SAND LAKE.

Minnesota Lake Eutrophication Analysis Procedure
ENTER INPUT VARIABLES
LAKE NAME ? LITTLE SAND
ECOREGION NUMBER 1=NLF,2=CHF,3=WCP,4=NGP ? 1
WATERSHED AREA (HA) ? 4910
LAKE SURFACE AREA (HA) ? 156
LAKE MEAN DEPTH (M) ? 6.9
OBSERVED MEAN LAKE TP (UG/L) ? 23
OBSERVED MEAN CHL-A (UG/L) ? 2.2
OBSERVED MEAN SECCHI (M) ? 5.3

INPUT DATA:
LAKE NAME =LITTLE SAND ECOREGION=NLF
LAKE AREA = 156 HA
WATERSHED AREA (EXCLUDING LAKE) = 4910 HA
MEAN DEPTH = 6.9 METERS
OBSERVED MEAN TP = 23 UG/L
OBSERVED MEAN CHL-A = 2.2 UG/L
OBSERVED MEAN SECCHI = 5.3 METERS

<press ENTER to view results>

LAKE = LITTLE SAND		ECOREGION = NLF	
AVERAGE INFLOW TP	= 53.11819 UG/L	TOTAL P LOAD	= 610.636 KG/YR
LAKE OUTFLOW	= 11.4958 HM3/YR	AREAL WATER LOAD	= 7.369102 M/YR
RESIDENCE TIME	= .9363421 YRS	P RETENTION COEF	= .4909023

VARIABLE	UNITS	OBSERVED	PREDICTED	STD ERROR	RESIDUAL	T-TEST
TOTAL P	(UG/L)	23.00	27.04	7.31	-0.07	-0.51
CHL-A	(UG/L)	2.20	8.15	4.33	-0.57	-2.20
SECCHI	(METERS)	5.30	2.25	0.83	0.37	2.17

NOTE: RESIDUAL = LOG10(OBSERVED/PREDICTED)
T-TEST FOR SIGNIFICANT DIFFERENCE BETWEEN OBS. AND PREDICTED

CHLOROPHYLL-A INTERVAL FREQUENCIES (%)

CHL-A PPB	OBSERVED	PREDICTED CASE A	PREDICTED CASE B	PREDICTED CASE C
10	0.03	25.20	26.87	33.28
20	0.00	1.74	2.56	8.62
30	0.00	0.16	0.32	2.81
60	0.00	0.00	0.00	0.22

CASE A = WITHIN-YEAR VARIATION CONSIDERED
CASE B = WITHIN-YEAR + YEAR-TO-YEAR VARIATION CONSIDERED
CASE C = CASE B + MODEL ERROR CONSIDERED

TABLE 4. RECKHOW - SIMPSON MODELING SUMMARY.

	LOW	MOST LIKE	HIGH	
	211.3	316.95	422.6	=Forested Flux
	0	0	0	=Ag flux
	127	158.75	190.5	=Urban flux
	9.325	18.65	27.975	=Wetland flux
	2.44	3.66	4.88	=Pasture/Open flux
	45.7	68.55	91.4	=Lake flux
	31.2	46.8	62.4	=Ppt flux
	19.86849	49.67123	79.47397	=Septic flux
	0	0	0	=Point Souce
	446.8334	663.0312	879.2289	=Total P Flux
	286.4317	425.0200	563.6083	= P LOAD
	0.014	0.02	0.027	=PREDICTED TP
		-1.69897		=LOG Pml
		0.006855		= + MODEL ERROR
		-0.00510		= - MODEL ERROR
		0.0035		= + LOADING ERROR
		0.003		= - LOADING ERROR
		0.007697		=TOTAL + UNCERTAIN
		0.005921		=TOTAL - UNCERTAIN
ug P/l	14	20	28	CONFIDENCE LIMITS

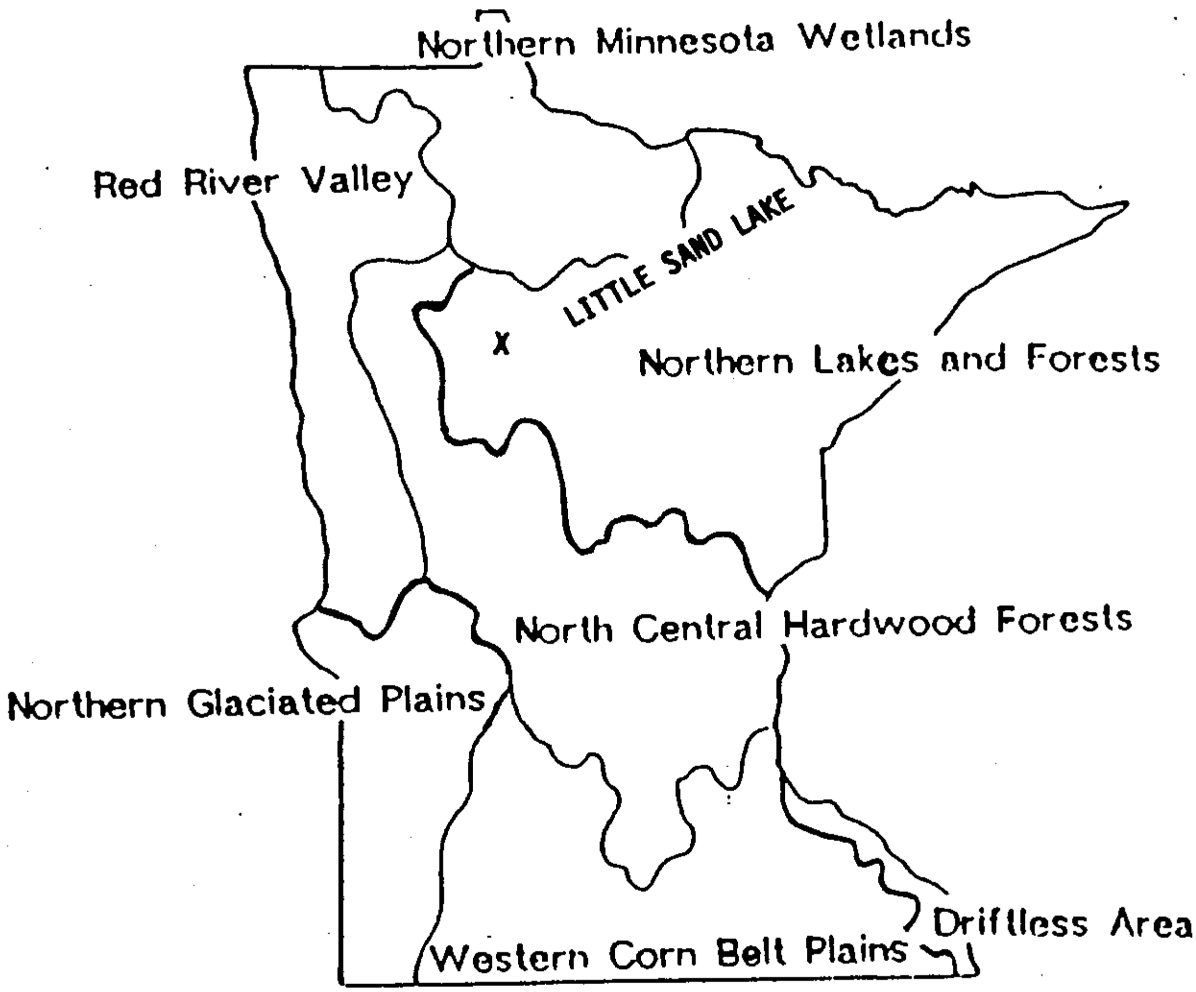


FIGURE 1. LITTLE SAND LAKE LOCATION MAP.
Minnesota's ecoregions noted.

FIGURE 2. LITTLE SAND LAKE BATHYMETRIC MAP.
Water quality sampling sites noted.

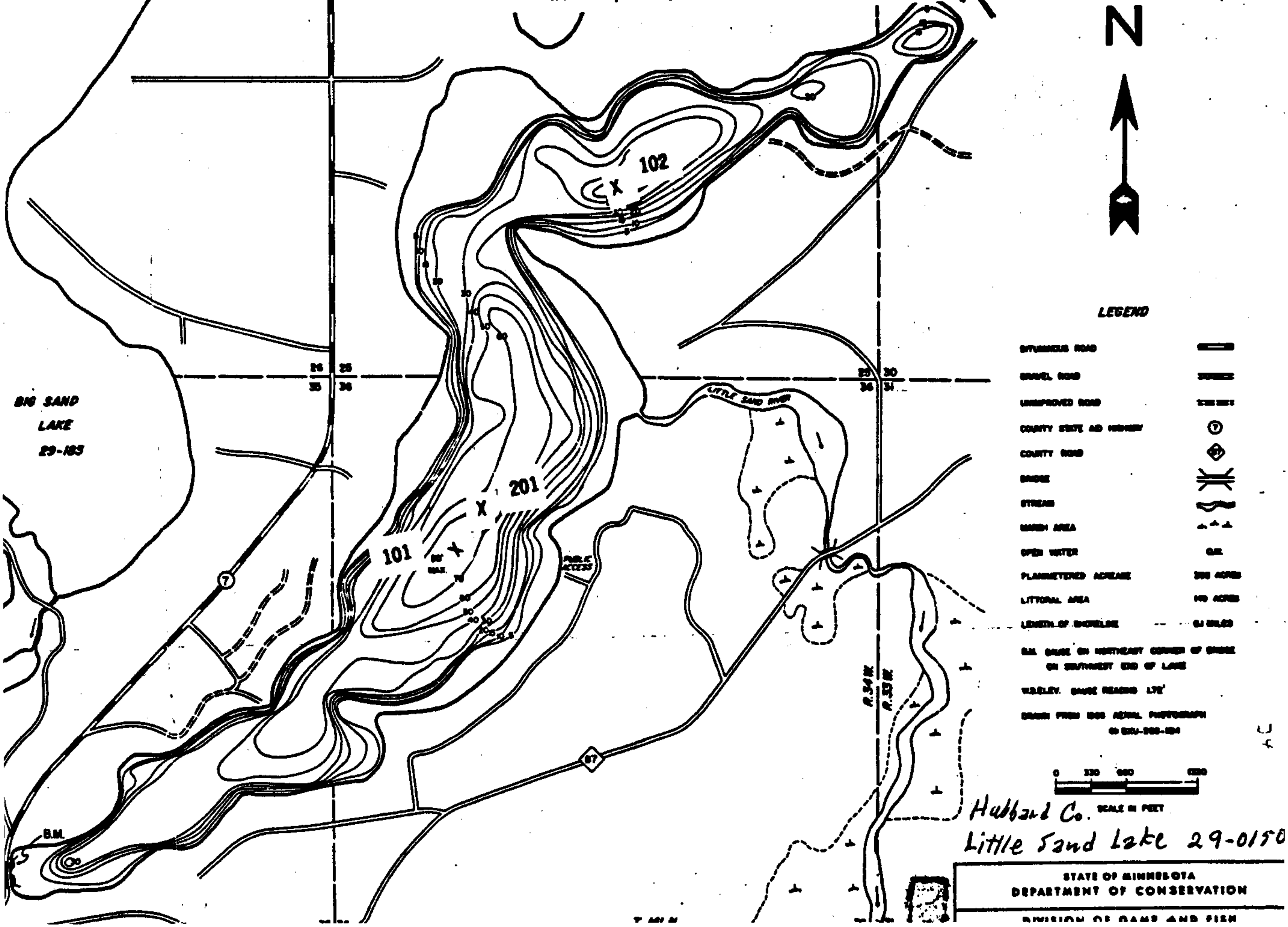
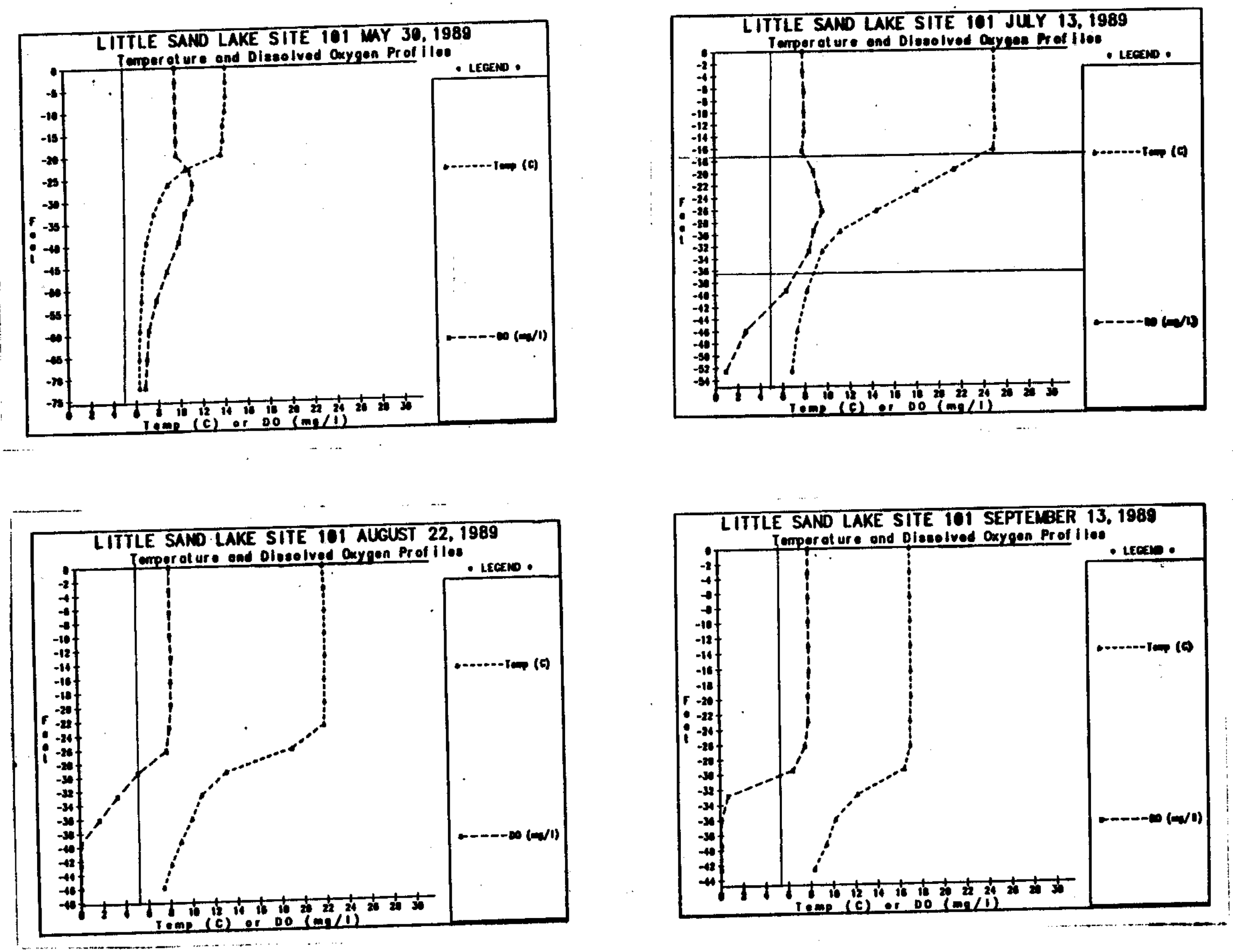
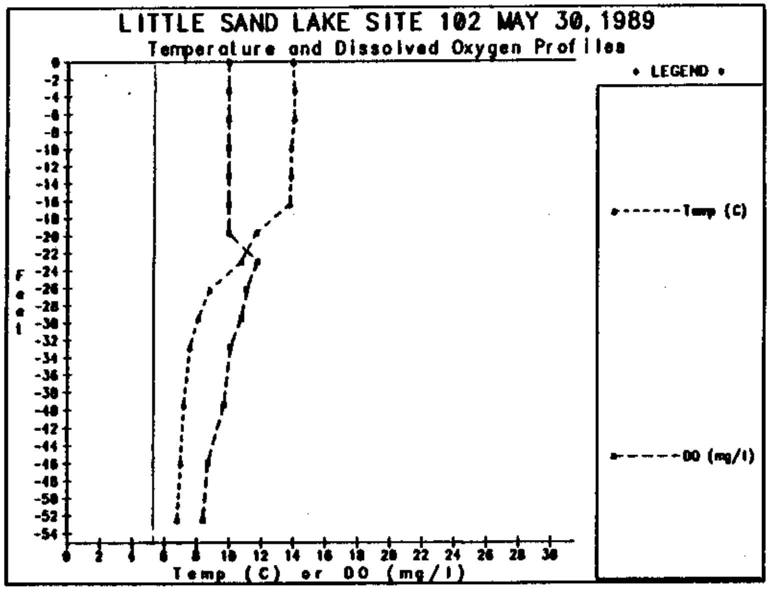


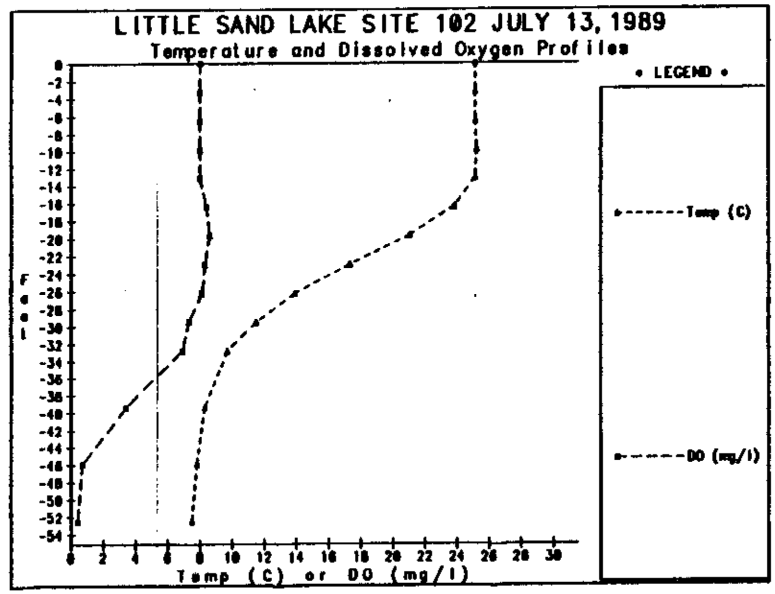
FIGURE 3. DISSOLVED OXYGEN AND TEMPERATURE PROFILES FOR LITTLE SAND LAKE.
Assorted profiles from various sample dates.

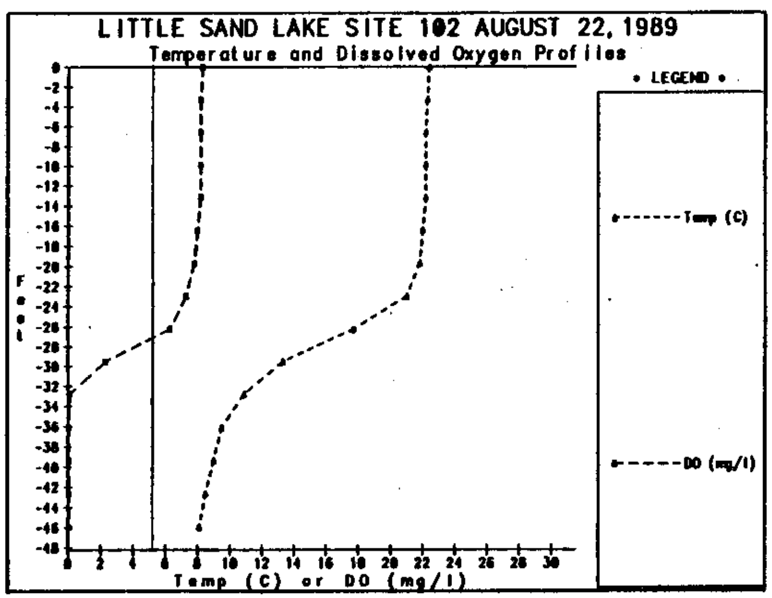


F3b

FIGURE 3. (cont.)







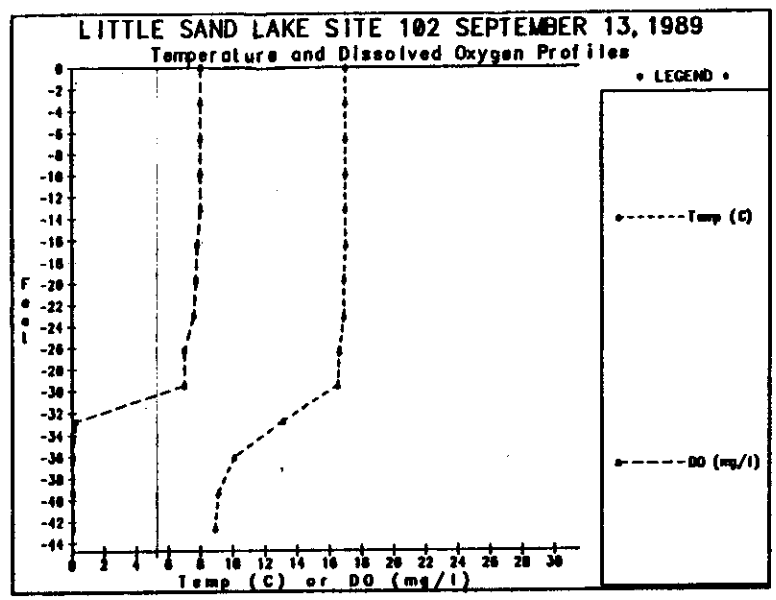
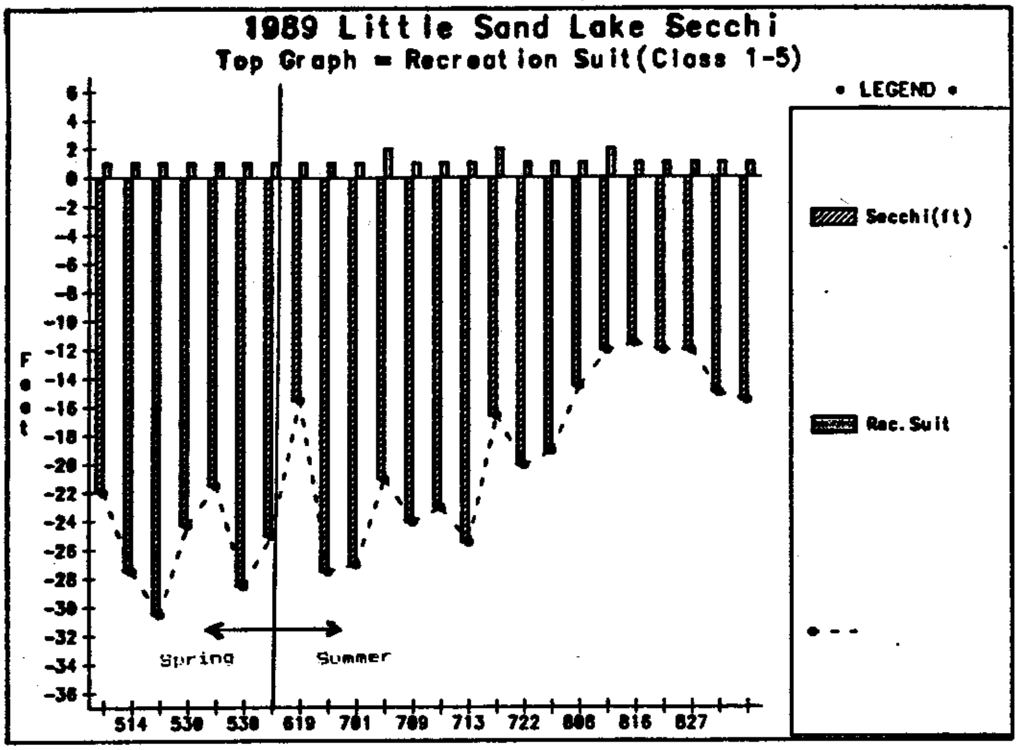
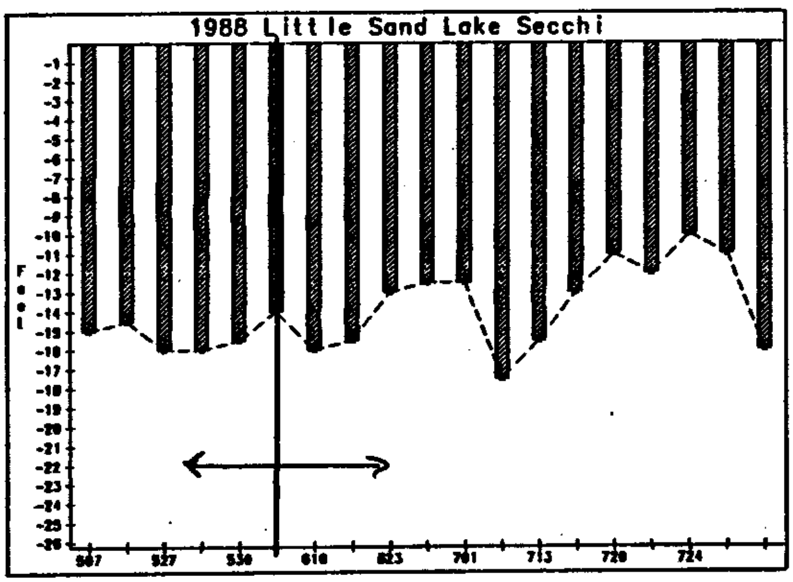
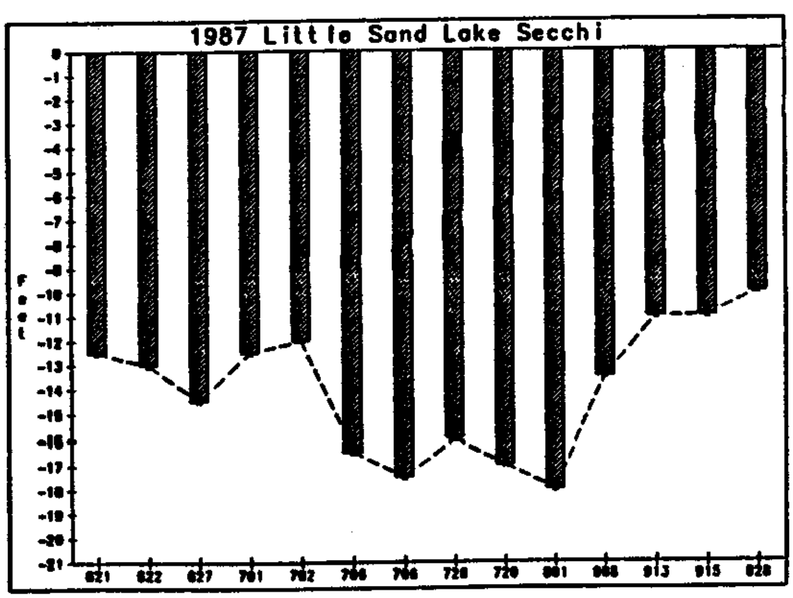


FIGURE 4. SECCHI TRANSPARENCY MEASUREMENTS. Data collected through Citizen Lake Monitoring Program.



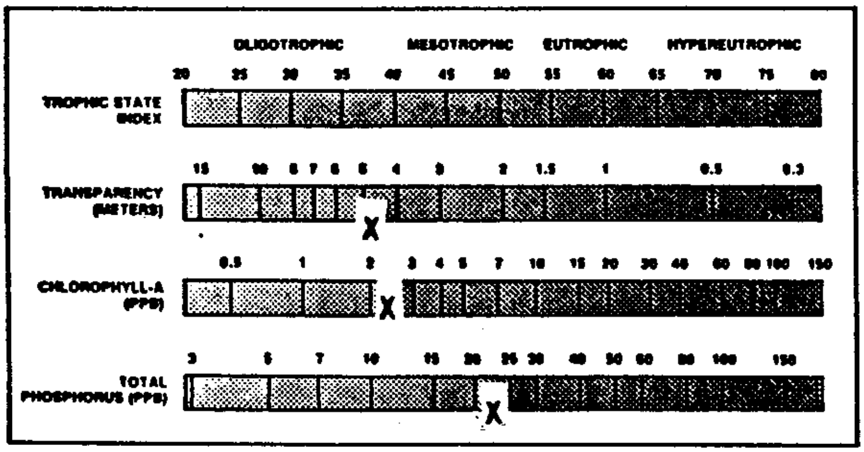




Changes in the Biological Condition of Lakes With Changes in Trophic State

R.E. Carlson

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



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

FIGURE 5. CARLSON'S TROPHIC STATE INDEX VALUES FOR LITTLE SAND LAKE. Based on mean summer data for 1988.

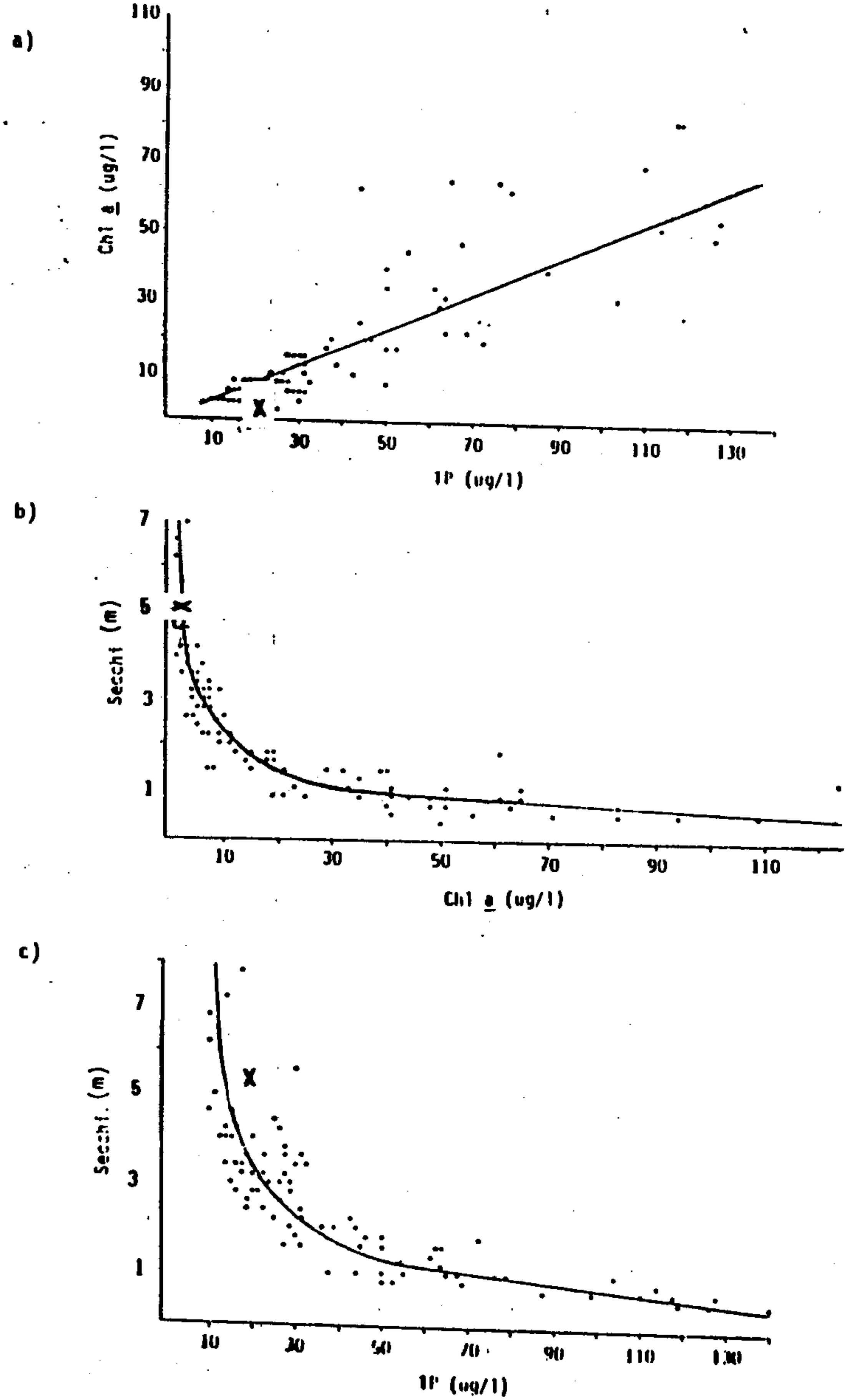


FIGURE 6. SCATTERPLOTS OF CHLOROPHYLL-a, TOTAL PHOSPHORUS AND SECCHI TRANSPARENCY. Based on summer mean observations from a set representative lakes from four ecoregions in Minnesota. Values for Little Sand Lake noted.

APPENDIX

1. Little Sand Lake Historical Summary
2. Little Sand Lake Water Quality Data
3. Little Sand Lake Lakeshore Development Map
4. Little Sand Lake Septic Survey
5. Additional Secchi Transparency Plots

APPENDIX A. CHRONOLOGICAL HISTORY OF LITTLE SAND LAKE.

CHRONOLOGICAL HISTORY

OF

LITTLE SAND LAKE
LAKE EMMA TOWNSHIP
HUBBARD COUNTY

1893 - First significant land purchase from the U.S. Government by August Welge. This is the site the Chateau Paulette is located on today. It is believed the Indians had lived on this land. A log cabin was built (year unknown).

1894 - Charles Kellner homesteaded and became the first permanent resident on Little Sand Lake, on what is now known as the "Norway Cove Estates". The bay this is located in, is still referred to as "Kellner's Bay". Charles married Emma Hensel in 1899 and all seven of their children were born on the homestead. Charles was a logger and farmer.

1890's- Sometime after the purchase of the land by Welge, the lob cabin became a trading post run by Buckskin Pearson. It became a place where trappers and loggers purchased their dry goods and gathered to spin tall tales.

1900's- Early in the new century, the trading post became a cook house for a logging camp and mill that was located on Lake Ida. Logs were boomed from the Kellner homestead, the entire length of Little Sand Lake to Lake Ida to the saw mill.

1909- - 1940 Charles Kellner started the first resort and it was named "Shady Knoll" - over the next few years, they built ten cabins (all log) and added onto their original log cabin to accommodate a dining room, large kitchen, plus living quarters. The log home and four cabins still remain today. By horse and buggy, they would pick-up their guests from the Great Northern Railroad Station in Dorset that was affectionately referred to as the "Blueberry Special". With the farm, the Kellner's provided all their own food for their guests.

1911 - By this time, no more logging was done on Little Sand Lake.

1915-1922 Very dry years and a dam was built on Little Sand River between Little Sand Lake and Round Lake to help. There was, for the first time, (and never since), no water flow between Big Sand and Lake Ida. Lake Belletaine residents were unset about this dam and they secretly hired someone to blow it up. The dam was replaced, only to be blown up again. It was never replaced and remnants of this dam can still be seen today. The dam was first built in the early 1920's and it was said to be very easy to build because the water was so low. As early as the early 1920's this chain of lakes were referred to as the Mantrap Valley - Little Sand Lake is in about center of this chain and Belletaine at the end (excluding the Crow Wing Lakes.)

1916 - First plat on Little Sand Lake "Angler's Woods" was platted by S.D. & Marian Whyte.

1917 - Converted from horse and buggy for transportation to automobile.

1918 - Second plat "Sabin Park" platted by John & Emily Sabin. Sometime in the 1920's this became the third resort on the lake. It is believed that they had a fire and lost most of their cabins and they were not rebuilt. It was not used as a resort for many years until much later when part of the plat was purchased to build "Little Sand Resort" (see 1969).

1920 - In the very early 1900's,the second resident, Alexander Lindberg came to Little Sand Lake and started a dairy farm and around 1920 he built the second resort on the lake that he named "Shoreham Shores Resort". It had four rental cabins and owners home and ceased being a resort in 1987. Many of the farm buildings still remain along with the house built by Alexander and is owned today by his daughter Katherine Lindberg Vokes.

1923 - Muskieland platted - the first homes on this plat was not until the 1950's.

1920-1960 Fourth resort on the lake called "Erv's Resort". When illness prevented the operation from continuing, it sat vacant until the 1970's when it was purchased by the Jacobsen family and the six cabins were restored and used for seasonal contract rentals.

1925-1967 Fifth resort on the lake was named "Camp Briggs" and later changed to "Mirimichi". It also had one other name that we were unable to find out. It is uncertain how many cabins that were on this resort, but it is believed to be less than what is there today. There are 12 seasonal cabins on Mirimichi today, individually owned.

1928 - The former trading post, then cook house for the sawmill was purchased by Leo & Anna Paulette and it became the Chateau Paulette. It became an eating and drinking establishment - cabins were added later - and there was a gas station. The eating and drinking establishment is still there, but only two cabins (used for storage) and the gas station has been gone a long time. The Chateau has been added on to several times, but the original log cabin is part of this Little Sand landmark and legand.

1936 - The last of the severe drought years

1945 - Mindianna platted - this plat contain 23 backlots that, as of yet, have not been developed - all lakeshore lots are developed.

1946 - Edmund Peterson purchased part of Anger's Woods and built an eight cabin resort that he named after the plat, "Angler's Woods Resort". It remained a resort until 1975, when Mr. Peterson donated it to the Lutheran Church for a camp. The Church sold the property in 1980 and it is now privately owned and shared by two families - all cabins are still used only seasonally.

1949 - County Road 7 was paved. (County Road 7 is located on the west side of the lake and stretches the entire length of Little Sand). It is not known when County Road 7 was first built, but we do know it was not here when Charles Kellner homesteaded in 1894. The first home built on the East side of the lake is believed to be in the late 20's or early 30's - the road could have come about the same time.

1955 - Northern Star Resort was to become the seventh resort on Little Sand. It was built by Ludwig Johnson - he built only four cabins and an owners cabin and passed away before he finished. Ludwig's widow sold the resort to the Slaughter's who added two more cabins to make six, before he sold it to Joe Morgan, who added two more cabins to make eight, and converted the owners cabin to make it a year around home. This resort is still in operation during the summer months only and is owned by the Alberg's. This is now the oldest existing resort in operation on the lake.

1957-1959 In the late 1950's the eighth resort was built and named "Greendale" by a Mr. Jones. It has six housekeeping cabins and an owners residence. This resort is still in operation today for summer only. It is owned by the Harrod's who recently purchased the resort in 1987.

1965 - Little Sand Lake was sprayed with an Orthro chemical by Joe Morgan who owned Northern Star Resort at the time. We were not able to find out the name of the chemical but it was attributed to Mr. Morgan's death. The entire lake was sprayed and it was for weed control. Little Sand had very few weeds until about 1985, it was noticed that there has been an increase.

1967 - Mirimichi was platted by the Fran Miller family. This had been a former resort.

1960 - Loch Vista Beach was platted - it ~~the~~ was platted mostly into 60 ft lots, but all owners (but 2) have at least two lots and some of them more.

1969 - The ninth and last resort to be built on Little Sand was started in Sabins Park by Harold and Lucille Albee, who have through the years built all but two of their 11 cabins and year around residence. The resort was named "Albee's Little Sand Resort" and is still in operation today. It is the only resort that is open for limited business in the winter - they have three units that are available in the winter months.

1975 - County Road 40 was paved. It is interesting to note that this road was not built where is is presently located until the 1970's due to the fact that where it is now located, use to be a wetland. (County Road 40 services the North end of Little Sand Lake - where the present day Norway Cove Estates is located. Mary Baldwin Kellner, who was born on Little Sand Lake in 1900, stated that each dry (drought) season left the land "less wet" than before, and that after 1936, there were no wetlands remaining where the present road is.

1978 - The Shoreham Shores was platted by Wallace and Katherine Vokes.

1960's- We are not sure of exactly when, but the State of Minnesota leased seventeen 100 foot lots on Little Sand. One of these lots has already been sold, and the other sixteen will be sold soon (owners have first option - or I should say leasee). The public access is in the midst of these leased lots.

1987 - Basswood Estates platted by Will Bedford. The pink lady slipper can be found on some of these lots.

Mel Luke begun doing the Secchi Disc readings on Little Sand Lake

1988 - The Little Sand Lake Area Association was formed. We have 126 land or property lowners on Little Sand and we have over 100 members. We send out a newsletter twice a year and we concentrate on education and stress the responsibility that comes with living in a lake community.

Bob Shotwell began doing a second Secchi disc reading on Little Sand representing the Association.

Charles Alberg begun to do Secchi Disc readings on Lake Ida for the Association (Lake Ida flows into Little Sand).

Opposed a proposal for 14 cabin resort that would be located on what is now Little Sand Acres due to the heavy commercial (It would have been between Chateau Paulette and Northern Star Resort with Walters Resort directly behind it on Lake Ida). The proposal was dropped and it was platted into five lots, or which only four will be developed.

1988 - Sought revisions on a plat submitted to the County that had over 30 lots (on what was to become the Norway Cove Estates). There were small wetlands that the Association had hoped not to be subdivided. A compromise was made (Plat ended up with only 10 lots) and the wetlands were better off than before but it still provided more fill than what was good for the health of the lake.

Norway Cove Estates was platted by Will Bedford. The pink lady slipper is still evident on this land. This is the former Kellner property - decentants of Mr. Kellner stated the lady slippers use to be by the hundreds - now they are easily counted.

1988 - Helped form the Hubbard County Coalition of Lake Associations

1988 - The Association applied to be accepted in LAP

1989 - Became involved in the MPCA Lake Assessment Program

Volunteered to read the water level gauge installed by the DNR on the bridge between Lake Ida and Little Sand.

Started an on going in depth project of doing a History on Little Sand-Gilmore Lake.

Gilmore Lake decided to become part of the Little Sand Association with representation on the Little Sand Board and the Hubbard County Coalition of Lake Associations (COLA) Board.

Installed and read rain gauge readings since late June

Two lots on the Norway Cove Estates exceeded fill limits. The Association called in the DNR, Corp of Engineers, and County. One lot was issued a restore order (but still exceeded as far as the Association can tell) - the DNR and Corp accepted what was done. The second lot couldn't be restored - they filled bogs.

Notified DNR of an artificial reef containing car battery, old drum, refrigator, and old dock. It was removed from Lake.

Sent a representative to the State Convention of Lake Associations at the Hyatt Regency Hotel in October.

NOTES ON THE LITTLE SAND LAKE WATERSHED (OVERLAND)

Loon Lake (just below Big Sand on the map) - has a culvert going to Big Sand, but water only flows into Big Sand from Loon once every 5 years in the Spring.

Beaver Lake - has underground flowage into watershed

The three pink sections on the map marked "OUT" all have high hills and the flowage is underground into watershed

Little Sand Lake is part of the Mantrap Valley Watershed - and the Mantrap Valley Watershed is part of a larger watershed called the Crow Wing Watershed

Bad Ax Lake is part of the Mantrap Valley Watershed (North of Mantrap Lake) but has not been included because is has underground flowage into the watershed.

Bill Alden did some ground truthing,as well as,members of the Association.

Little Sand Lake is spring fed. Plats that we know of that have springs on them are: Shoreham Shores, Norway Cove Estates, Basswood Estates, Muskieland, and Little Sand Acres.

APPENDIX B. LITTLE SAND LAKE WATER QUALITY DATA.

-- LAKEID=29-0150 --

DATE	SITE	D	TP	TKN	N2N3	TSS	TSIN	ALK	PH	CL	COND	TURB	COLOR	CHLA	SD	PHYS	REC
870621	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.8100		
870622	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.9624		
870627	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.4196		
870701	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.8100		
870702	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.6576		
870706	201	0	.	.	.	.	.	.	.	.	.	.	.	.	5.0292		
870706	201	0	.	.	.	.	.	.	.	.	.	.	.	.	5.3340		
870720	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.8768		
870720	201	0	.	.	.	.	.	.	.	.	.	.	.	.	5.1816		
870801	201	0	.	.	.	.	.	.	.	.	.	.	.	.	5.4864		
870908	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.1148		
870913	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.3528		
870915	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.3528		
870928	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.0480		
871017	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.9624		
871031	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.5720		
871108	201	0	.	.	.	.	.	.	.	.	.	.	.	.	6.0960		
880425	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.8768		
880426	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.8768		
880516	201	0	.	.	.	.	.	.	.	.	.	.	.	.	6.0960		
880531	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.5720		
880604	202	0	.	.	.	.	.	.	.	.	.	.	.	.	4.4196	1	1
880610	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.8768		
880613	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.8768		
880619	202	0	.	.	.	.	.	.	.	.	.	.	.	.	4.7244	1	1
880625	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.2672		
880626	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.8768		
880627	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.7244		
880701	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.9624		
880701	202	0	.	.	.	.	.	.	.	.	.	.	.	.	4.4196	1	1
880702	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.8100		
880712	202	0	.	.	.	.	.	.	.	.	.	.	.	.	3.8100	1	1
880718	201	0	.	.	.	.	.	.	.	.	.	.	.	.	5.3340		
880723	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.7244		
880725	202	0	.	.	.	.	.	.	.	.	.	.	.	.	3.9624	1	1
880817	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.3528		
880819	202	0	.	.	.	.	.	.	.	.	.	.	.	.	3.6576	1	1
880820	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.0480		
880822	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.3528		
880926	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.8768		
881008	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.8768		
881008	201	0	.	.	.	.	.	.	.	.	.	.	.	.	5.1816		
881011	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.5720		
890507	201	0	.	.	.	.	.	.	.	.	.	.	.	.	6.7056	1	1
890514	201	0	.	.	.	.	.	.	.	.	.	.	.	.	8.3820	1	1
890527	201	0	.	.	.	.	.	.	.	.	.	.	.	.	9.2964	1	1
890530	101	0	0.010	0.42	0.01	1	0.2	160	8.55	1.8	.	0.28	5	0.8	7.4000	1	1
890530	101	72	0.024	0.61	0.19	.	.	.	.	.	.	.	.	.	.		
890530	102	0	0.010	0.41	0.05	.	.	.	.	.	.	.	.	.	6.5500		
890530	201	0	.	.	.	.	.	.	.	.	.	.	.	.	8.6868	1	1
890610	201	0	.	.	.	.	.	.	.	.	.	.	.	.	7.6200	1	1
890619	202	0	.	.	.	.	.	.	.	.	.	.	.	.	4.7244		
890623	201	0	.	.	.	.	.	.	.	.	.	.	.	.	8.3820	1	1
890701	201	0	.	.	.	.	.	.	.	.	.	.	.	.	8.2296	1	1

LAKEID=29-0150

DATE	SITE	D	TP	TKN	N2N3	TSS	TSIN	ALK	PH	CL	COND	TURB	COLOR	CHLA	SD	PHYS	REC
890701	202	0	.	.	.	.	.	.	.	.	.	.	.	.	6.4008	1	2
890709	201	0	.	.	.	.	.	.	.	.	.	.	.	.	7.3152	1	1
890713	101	0	0.046	0.22	0.01	1.4	.	140	8.6	1.8	.	0.70	10	1.76	7.0000	1	1
890713	102	0	0.043	0.29	.	.	.	.	8.7	.	.	.	.	1.12	7.7500	1	1
890720	202	0	.	.	.	.	.	.	.	.	.	.	.	.	5.0292	2	2
890722	201	0	.	.	.	.	.	.	.	.	.	.	.	.	6.0960	1	1
890724	201	0	.	.	.	.	.	.	.	.	.	.	.	.	5.7912	1	1
890808	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.4196	2	1
890813	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.6576	2	1
890816	202	0	.	.	.	.	.	.	.	.	.	.	.	.	3.6576	2	2
890822	101	0	0.016	0.45	0.01	2.6	1.2	150	8.7	2.0	.	1.50	5	2.88	3.5000	2	1
890822	102	0		0.42	.	.	.	.	8.7	.	.	.		2.40	3.6500	2	1
890827	201	0	.	.	.	.	.	.	.	.	.	.	.	.	3.6576	2	1
890902	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.5720	2	1
890905	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.7244	2	1
890913	101	0	0.019	0.51	0.01	1.4	0.8	170	.	2.8	.	0.93	5	1.92	3.3500	1	1
890913	102	0	0.016	0.39	0.01	.	.	.	.	.	.	.	.	3.04	3.5000	1	1
890915	202	0	.	.	.	.	.	.	.	.	.	.	.	.	4.2672	2	2
890917	201	0	.	.	.	.	.	.	.	.	.	.	.	.	4.4196	2	1

Abbreviations and Units

SITE= sampling site ID
DM= sample depth in meters(0=0-2 m integrated)
D= sample depth in feet
TP= total phosphorus in mg/l
TKN= total Kjeldahl nitrogen in mg/l
N2N3= nitrite+nitrate N in mg/l
PH= pH in SU (field)
ALK= alkalinity in mg/l (lab)
TSS= total suspended solids in mg/l
TURB= turbidity in NTU
COND= conductivity in umhos/cm
CL= chloride in mg/l
SD= secchi disk in meters
CHLA= chlorophyll a in ug/l

/TYPA/AMBNT/LAKE/BIO

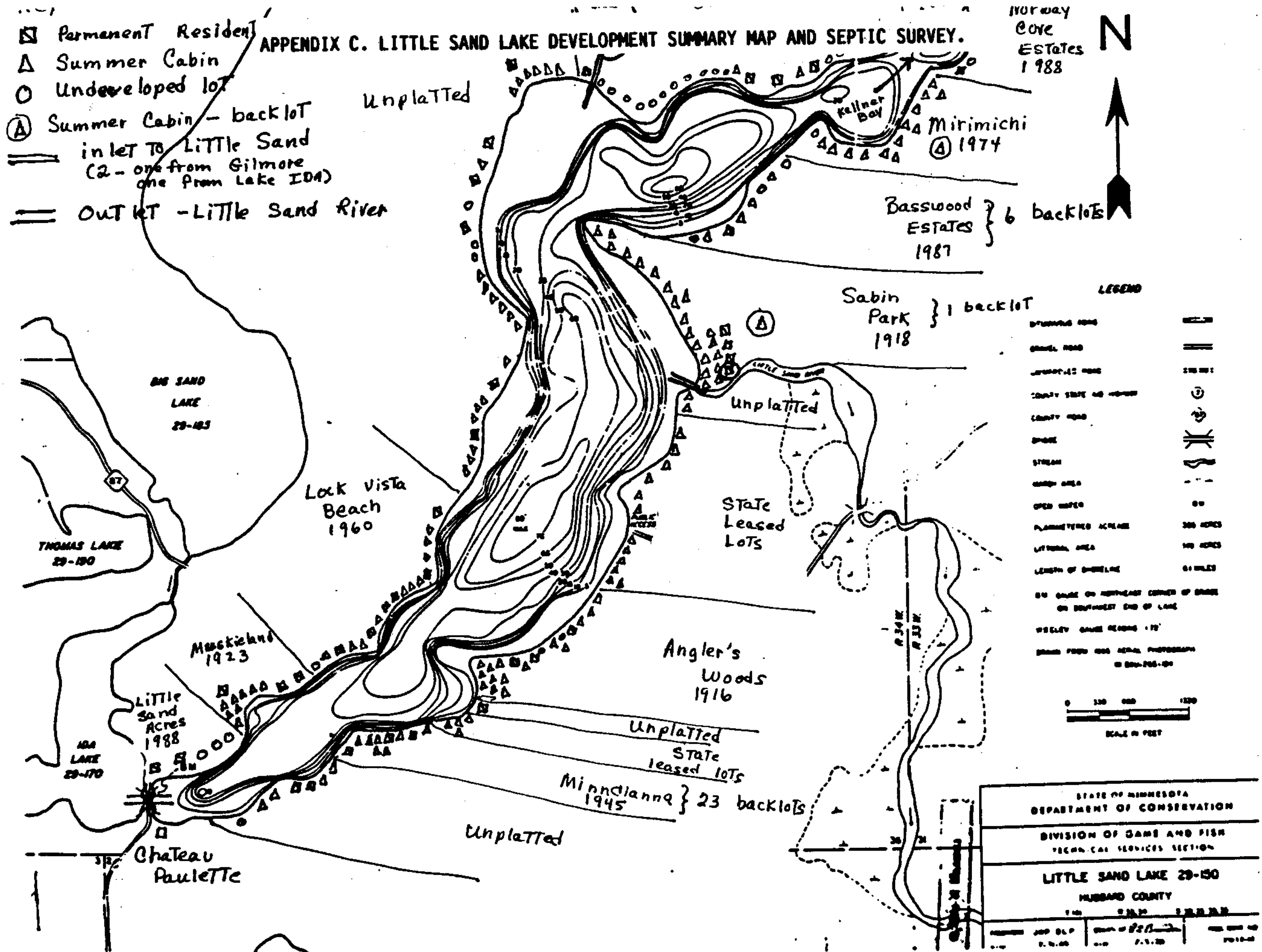
29-0150
46 59 26.0 094 55 53.0 3
LAKE: LITTLE SAND 2 MI NE OF DORSET
27057 MINNESOTA HUBBARD
AREA: 156.2 HECTARE M 070312
MEAN DEPTH: - M MAX DEPTH: 24.4 M
21MINNL 871114 07010106
0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	MEDIUM	SMK OR DEPTH (FT)	00029 FIELD IDENT NUMBER	00098 VSAMPLOC DEPTH METERS	00300 DO MG/L	00301 DO SATUR PERCENT	00010 WATER TEMP CENT	00011 WATER TEMP FAHN
89/05/30	1605	WATER	0	101	.00	9.9		14.4	
89/05/30	1605	WATER	3.28	101	1.00	9.9		14.4	
89/05/30	1605	WATER	6.56	101	2.00	9.9		14.4	
89/05/30	1605	WATER	9.84	101	3.00	9.9		14.3	
89/05/30	1605	WATER	13.12	101	4.00	9.9		14.1	
89/05/30	1605	WATER	16.4	101	5.00	9.9		14.1	
89/05/30	1605	WATER	19.68	101	6.00	9.9		13.9	
89/05/30	1605	WATER	22.96	101	7.00	11.0		10.7	
89/05/30	1605	WATER	26.24	101	8.00	11.3		9.1	
89/05/30	1605	WATER	29.52	101	9.00	11.2		8.4	
89/05/30	1605	WATER	32.8	101	10.00	10.6		7.8	
89/05/30	1605	WATER	39.36	101	12.00	10.0		7.1	
89/05/30	1605	WATER	45.92	101	14.00	8.9		6.7	
89/05/30	1605	WATER	52.48	101	16.00	7.9		6.6	
89/05/30	1605	WATER	59.04	101	18.00	7.2		6.4	
89/05/30	1605	WATER	65.6	101	20.00	7.0		6.3	
89/05/30	1605	WATER	72.16	101	22.00	6.8		6.3	
89/05/30	1645	WATER	0	102	.00	10.0		14.0	
89/05/30	1645	WATER	3.28	102	1.00	10.0		14.1	
89/05/30	1645	WATER	6.56	102	2.00	10.0		14.1	
89/05/30	1645	WATER	9.84	102	3.00	10.0		13.9	
89/05/30	1645	WATER	13.12	102	4.00	10.0		13.9	
89/05/30	1645	WATER	16.4	102	5.00	10.0		13.8	
89/05/30	1645	WATER	19.68	102	6.00	10.0		11.7	
89/05/30	1645	WATER	22.96	102	7.00	11.8		10.8	
89/05/30	1645	WATER	26.24	102	8.00	11.1		8.8	
89/05/30	1645	WATER	29.52	102	9.00	10.8		8.1	
89/05/30	1645	WATER	32.8	102	10.00	10.1		7.6	
89/05/30	1645	WATER	39.36	102	12.00	9.7		7.2	
89/05/30	1645	WATER	45.92	102	14.00	8.7		7.0	
89/05/30	1645	WATER	52.48	102	16.00	8.4		6.8	
89/07/13	1130	WATER	0	101	.00	7.9		25.0	
89/07/13	1130	WATER	3.28	101	1.00	7.9		25.0	
89/07/13	1130	WATER	6.56	101	2.00	8.0		25.0	
89/07/13	1130	WATER	9.84	101	3.00	8.0		25.0	
89/07/13	1130	WATER	13.12	101	4.00	8.0		25.1	
89/07/13	1130	WATER	16.4	101	5.00	7.8		24.9	
89/07/13	1130	WATER	19.68	101	6.00	8.8		21.4	
89/07/13	1130	WATER	22.96	101	7.00	9.2		18.0	
89/07/13	1130	WATER	26.24	101	8.00	9.6		14.4	
89/07/13	1130	WATER	29.52	101	9.00	8.8		11.2	
89/07/13	1130	WATER	32.8	101	10.00	8.4		9.6	
89/07/13	1130	WATER	39.36	101	12.00	6.3		8.2	
89/07/13	1130	WATER	45.92	101	14.00	2.7		7.3	
89/07/13	1130	WATER	52.48	101	16.00	.9		6.8	
89/07/13	1215	WATER	0	102	.00	8.0		25.1	

89/07/13	1215	WATER	3.28	102	1.00	8.0	25.1
89/07/13	1215	WATER	6.56	102	2.00	8.0	25.1
89/07/13	1215	WATER	9.84	102	3.00	8.0	25.2
89/07/13	1215	WATER	13.12	102	4.00	8.0	25.1
89/07/13	1215	WATER	16.4	102	5.00	8.4	23.8
89/07/13	1215	WATER	19.68	102	6.00	8.6	21.0
89/07/13	1215	WATER	22.96	102	7.00	8.3	17.3
89/07/13	1215	WATER	26.24	102	8.00	8.1	13.9
89/07/13	1215	WATER	29.52	102	9.00	7.3	11.5
89/07/13	1215	WATER	32.8	102	10.00	6.9	9.7
89/07/13	1215	WATER	39.36	102	12.00	3.4 ←	8.3 ←
89/07/13	1215	WATER	45.92	102	14.00	.7	7.8
89/07/13	1215	WATER	52.48	102	16.00	.4	7.5
89/08/22	1030	WATER	0	101	.00	8.3	22.0
89/08/22	1030	WATER	3.28	101	1.00	8.3	22.1
89/08/22	1030	WATER	6.56	101	2.00	8.3	22.1
89/08/22	1030	WATER	9.84	101	3.00	8.3	22.1
89/08/22	1030	WATER	13.12	101	4.00	8.4	22.1
89/08/22	1030	WATER	16.4	101	5.00	8.3	22.0
89/08/22	1030	WATER	19.68	101	6.00	8.3	22.0
89/08/22	1030	WATER	22.96	101	7.00	8.1	21.9
89/08/22	1030	WATER	26.24	101	8.00	7.8	19.0
89/08/22	1030	WATER	29.52	101	9.00	5.2 ←	13.1
89/08/22	1030	WATER	32.8	101	10.00	3.4	10.9 ←
89/08/22	1030	WATER	36.08	101	11.00	1.7	10.0
89/08/22	1030	WATER	39.36	101	12.00	.1	9.0
89/08/22	1030	WATER	42.64	101	13.00	.05	8.1
89/08/22	1030	WATER	45.92	101	14.00	.05	7.4
89/08/22	1145	WATER	0	102	.00	8.3	22.4
89/08/22	1145	WATER	3.28	102	1.00	8.2	22.3
89/08/22	1145	WATER	6.56	102	2.00	8.2	22.2
89/08/22	1145	WATER	9.84	102	3.00	8.2	22.2
89/08/22	1145	WATER	13.12	102	4.00	8.2	22.2
89/08/22	1145	WATER	16.4	102	5.00	8.0	22.0
89/08/22	1145	WATER	19.68	102	6.00	7.8	21.8
89/08/22	1145	WATER	22.96	102	7.00	7.3	21.0
89/08/22	1145	WATER	26.24	102	8.00	6.3	17.7 ←
89/08/22	1145	WATER	29.52	102	9.00	2.3 ←	13.3
89/08/22	1145	WATER	32.8	102	10.00	.1	10.9
89/08/22	1145	WATER	36.08	102	11.00	.05	9.5
89/08/22	1145	WATER	39.36	102	12.00	.05	9.0
89/08/22	1145	WATER	42.64	102	13.00	.05	8.5
89/08/22	1145	WATER	45.92	102	14.00	.05	8.1
89/09/13	1100	WATER	0	101	.00	8.0	17.1
89/09/13	1100	WATER	3.28	101	1.00	8.0	17.1
89/09/13	1100	WATER	6.56	101	2.00	8.0	17.1
89/09/13	1100	WATER	9.84	101	3.00	8.0	17.1
89/09/13	1100	WATER	13.12	101	4.00	8.0	17.1
89/09/13	1100	WATER	16.4	101	5.00	8.0	17.1
89/09/13	1100	WATER	19.68	101	6.00	7.9	17.1
89/09/13	1100	WATER	22.96	101	7.00	7.9	17.0
89/09/13	1100	WATER	26.24	101	8.00	7.6	17.0
89/09/13	1100	WATER	29.52	101	9.00	6.5	16.4
89/09/13	1100	WATER	32.8	101	10.00	.7 ←	12.2 ←
89/09/13	1100	WATER	36.08	101	11.00	.1	10.2
89/09/13	1100	WATER	39.36	101	12.00	.1	9.4
89/09/13	1100	WATER	42.64	101	13.00	.05	8.3
89/09/13	1145	WATER	0	102	.00	8.0	17.0
89/09/13	1145	WATER	3.28	102	1.00	8.0	17.0
89/09/13	1145	WATER	6.56	102	2.00	8.0	17.0
89/09/13	1145	WATER	9.84	102	3.00	8.0	17.0
89/09/13	1145	WATER	13.12	102	4.00	8.0	17.0
89/09/13	1145	WATER	16.4	102	5.00	7.8	17.0
89/09/13	1145	WATER	19.68	102	6.00	7.7	16.9

89/09/13	1145	WATER	22.96	102	7.00	7.6	16.9
89/09/13	1145	WATER	26.24	102	8.00	7.0	16.6
89/09/13	1145	WATER	29.52	102	9.00	7.0	16.5
89/09/13	1145	WATER	32.8	102	10.00	.2 ←	13.1 ←
89/09/13	1145	WATER	36.08	102	11.00	.05	10.1
89/09/13	1145	WATER	39.36	102	12.00	.05	9.1
89/09/13	1145	WATER	42.64	102	13.00	.05	8.9

APPENDIX C. LITTLE SAND LAKE DEVELOPMENT SUMMARY MAP AND SEPTIC SURVEY.



REFERENCE MAP IMPORTANT - NOT DONE TO SCALE

LITTLE SAND LAKE DEVELOPMENT
SEPTIC SURVEY

SEPTIC SURVEY - 1989

56 contained tank septics with drainfields have been installed since 1980 - this number includes new housing, first time septics, and replaced septics of old systems.

14 septics installed in the 1970's and they have seepage tanks with drainfields

60 pre-1970 systems - 43 of these are seepage tanks with drainfields (the drainfields were added without replacing the old system) - 5 with seepage tanks with no drainfields - 2 cesspools - and 10 are unknown.

31 without septics (they have outside sanitary facility) - it is projected that most of these will add septic systems with-in 5 years.

1 Commercial restrauant with seating capacity of 400 - this system failed in 1975 - new system installed in 1979 500 gal lift pump station to two 1,000 gal. tanks that goes into old drainfield - we were unable to obtain any information about the old drainfield. The volume demand has reduced drastically since 1979 (they converted from plates to baskets - in last five years they have also targeted their market for the bar rather than dinners - before 1985 they consistently over crowded and exceeded the 400 seating capacity - since 1985 it is doubtful that they have reached their 400 seating capacity at any given time. This restrauant is open everyday throughout the summer and with Labor Day it is open on week-ends only in the winter (until Memorial Day).

DEVELOPMENT - 1989 Survey

32 lots undeveloped - indications are at least 20 of these lots will be built on within 5 years.

33 year around residents

106 seasonal cabins - 10 of these were built as permanent housing intended for retirement homes and will be used as such within 5 years.

25 resort cabins (3 resorts on the lake) - three of these cabins are used for winter business

1 commercial restrauant

1 cabin second tier development

30 lots in four plats (Minndianna, Sabin Park, Basswood, and Norway Cove) that are 2nd, 3rd or four tier plats

APPENDIX D. LITTLE SAND LAKE SWIM-LAKE DATA FILE SUMMARY.

SWIM-LAKE SUMMARY DATA FILE

Lake name: LITTLE SAND DNR Division of Waters lake number 29- 150
Primary county: HUBBARD Secondary county: HUBBARD
Lake LITTLE SAND is in 1 county
Location: Township 141 Range 33,34
Watershed CROW WING

ENTER	REPORT
PHY	for physical characteristics
DEV	for development characteristics
FIS	for the fish report
PER	for permit characteristics
ALL	for all four reports
B	to go back one menu (lake choice)
C	to go back two menus (county choice)
Q	to leave this data base

Enter the report or MENU: all

PHYSICAL CHARACTERISTICS FOR LAKE: LITTLE SAND

Dominant forest/soil type: CONIFER/SAND
Size of lake: 437 Acres Shorelength: 6.3 Miles.
Maximum depth: 80.0 Median depth: 22.0

Secchi disk reading (water clarity): NA
Lake contour map number: C1998 (available at cost from Documents Division)
(phone: 612-297-3000)

DEVELOPMENT CHARACTERISTICS FOR LAKE: LITTLE SAND

Shoreland zoning classification: RECREATIONAL DEVELOPMENT
Public accesses in 1986: 1

Development	Seasonal Homes	Permanent Homes	Total Homes
1967	26	7	33
1982	56	10	66

*** PUSH RETURN TO CONTINUE ***

DNR SECTION OF FISHERIES INFORMATION FOR LAKE LITTLE SAND

DEVELOPMENT - 1982 - from DNR Survey

56 seasonal homes

10 permanent homes

Total of 66 living structures on the lake

DEVELOPMENT - 1967 - from DNR Survey

26 seasonal homes

7 permanent homes

Total of 33 living structures on the lake

SUMMARY

In only seven years (since the 1982 DNR survey), Little Sand Lake has increased 100% in their seasonal homes and over 300% in their permanent homes. Of the 106 seasonal cabins on Little Sand today, 16 of these are State leased lots. It is unfortunate the State did not have the forsight to keep the land (without leasing) for the protection of Little Sand. We have only one parcel of land over 1,000 feet that has not been platted yet and we have the potential of second, thrid, and fourth tier development - all on a lake,because of it's size,should have been classified as an environmental development lake. We have very little left, but to use education to help protect the lake. The Association sent out a survey and 83% of the respondants wanted septic monitoring - that is encouraging.

The Lake Assessment Program (LAP) was an excellent opportunity to meet with each of our residents. We used the opportunity to inform them of what the Lake Association has been doing, gave out copies of "How to Take Care of Your Septic System", had brochures on the Purple Loosestrife, made sure they had a copy of "Citizen's Guide to Lake Protection", and collected dues (some joined the Association for the first time).

We have enclosed a copy of our lake marking the development. We should also note that the Plat, Shoreham Shores has five lots (not included in the backlots total listed earlier in this report), that are on Gilmore Lake - all within 500 feet of Little Sand Lake (some less than 200 feet). Three of the five have seasonal homes.

INFORMATION FROM THE DNR:

Water Surface area: 386 acres Size of Lake: 437 acres
Miles of Shoreline: 6.4 miles
Max. Depth: 80 feet Medium Depth: 22.0

FISH POPULATION COMMENTS

THE WALLEYE POPULATION APPEARS TO BE ABOVE AVERAGE

*** PUSH RETURN FOR STOCKING DATA ***

FISH STOCKING DATA

year	species	size	# released
79	Walleye	FRY	520000
79	Muskellunge	FINGERLING	450
79	Walleye	FRY	300
80	Walleye	FRY	500000
80	Muskellunge	ADULT	184
80	Muskellunge	YEARLING	198
81	Walleye	FRY	500000
81	Walleye	FINGERLING	10800
82	Bluegill Sunfish	YEARLING	894
82	Walleye	FINGERLING	12750
83	Walleye	FRY	500000
84	Walleye	FRY	600000
85	Walleye	FRY	500000
86	Walleye	FRY	1300000
87	Walleye	FRY	1500000

*** PUSH RETURN FOR PERMIT DATA ***

PERMIT DATA FOR LAKE LITTLE SAND

SUMMARY OF DNR PERMIT
APPLICATIONS ISSUED OR DENIED AS OF JUNE 1986 FOR LAKE: LITTLE SAND

PERMIT TYPES:	NUMBER ISSUED	NUMBER DENIED
PUBLIC (PROTECTED) WATERS PERMITS		
Sand blanket	3	0
Excavation	3	0
GENERAL APPROPRIATION PERMITS	0	0

WATER CHEMISTRY

SURVEY DATE: 06/29/1987

Secchi disk: 14.0
% Littoral: 38

Water color: CLEAR
Cause of water color: MARL BOTTOM

LAKE DESCRIPTION

Surface water area: 386
Management class: WALLEYE-CENTRARCHID
Ecological type: CENTRARCHID-WALLEYE

Accessibility: EAST SIDE OF THE LAKE, SECTION 36 OWNED BY DNR.

Area fisheries supervisor: DENNIS ERNST (218) 732-4153
PO BOX 271 PARK RAPIDS 56470

*** PUSH RETURN FOR CATCH DATA ***

NET CATCH DATA

GILL NETS No. of sets: 6 Gill net survey date: 6/29/1987

species	# fish	# per set	total pounds	pounds per set
Northern Pike	18	3.0	25.80	4.30
Rock Bass	1	0.2	0.70	0.12
	1	0.2	1.20	0.20
Tulibee (Inl.Cisco)	4	0.7	11.20	1.87
Walleye	45	7.5	21.00	3.50
White Sucker	38	6.3	89.00	14.83
Yellow Perch	24	4.0	5.20	0.87

TRAP NETS No. of sets: 15 Trap survey date: 6/29/1987

species	# fish	# per set	total pounds	pounds per set
Black Bullhead	1	0.1	0.90	0.06
Black Crappie	4	0.3	4.40	0.29
Bluegill Sunfish	57	3.8	19.80	1.32
Largemouth Bass	2	0.1	0.40	0.03
Northern Pike	9	0.6	9.00	0.60

More (Y/N):

species	# fish	# per set	total pounds	pounds per set
Pumpkinseed Sunfish	14	0.9	4.20	0.28
Rock Bass	28	1.9	6.80	0.45
Smallmouth Bass	2	0.1	0.30	0.02
Walleye	1	0.1	0.60	0.04
Yellow Bullhead	7	0.5	7.70	0.51
Yellow Perch	10	0.7	1.50	0.10

*** PUSH RETURN FOR FISH COMMENTS ***

APPENDIX E. LAKE LEVEL DATA.

MnDNR Division of Waters LAKES-DB
WATER LEVEL SUMMARY

Report Date 02/28/90

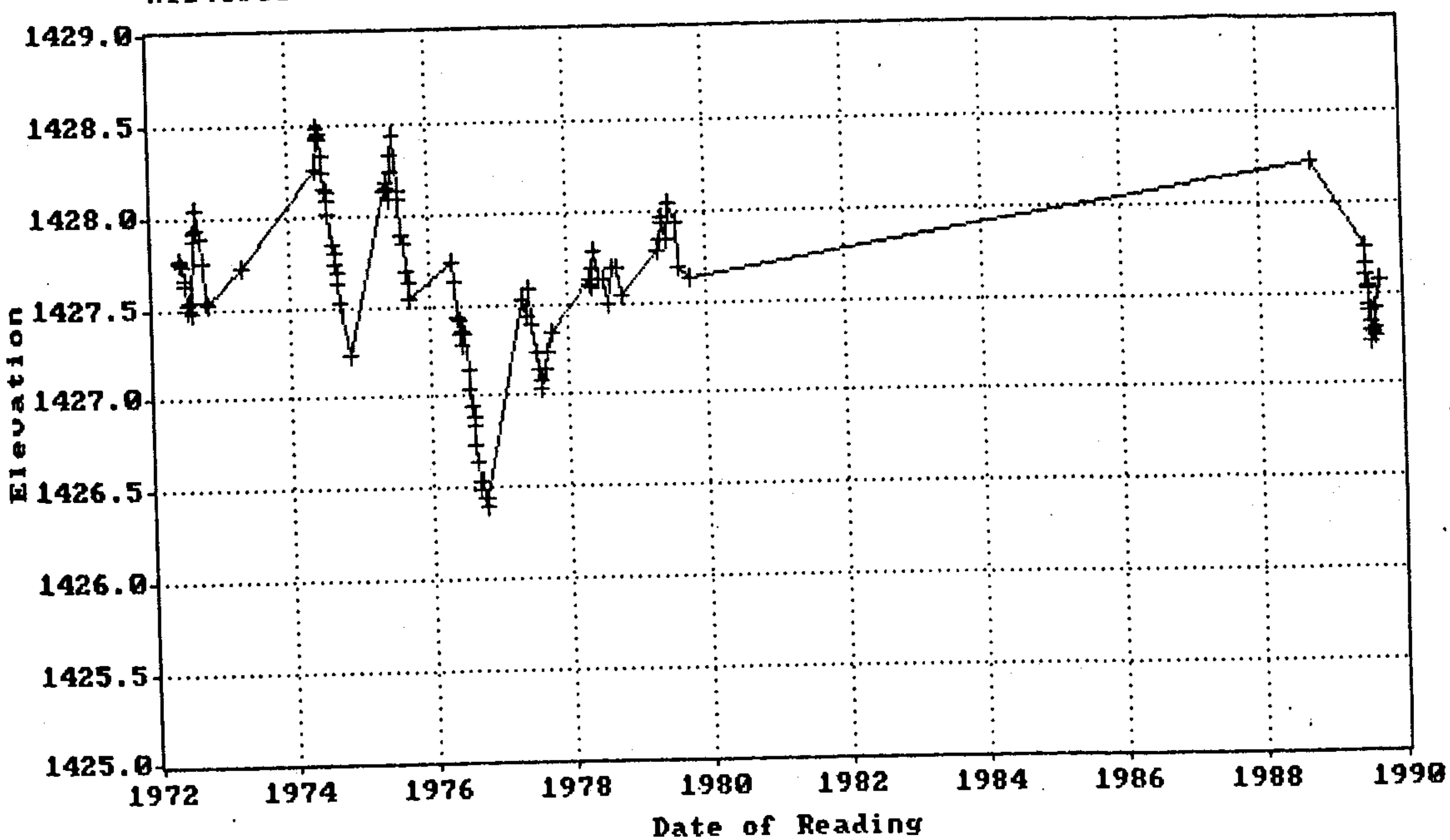
LITTLE SAND LAKE HUBBARD COUNTY
ID 29-0150 Sub-basin 00
Region 1 Area 2

YEAR	MAX (DATE)	MIN (DATE)	RANGE	AVG	# READINGS
1989	1427.75 (07/06/89)	1427.24 (08/10/89)	0.51	1427.43	17
1988	1428.23 (10/05/88)	1428.23 (10/05/88)		1428.23	1
1979	1428.04 (06/21/79)	1427.64 (10/13/79)	0.40	1427.86	10
1978	1427.79 (05/29/78)	1427.49 (07/29/78)	0.30	1427.64	12
1977	1427.59 (06/03/77)	1427.04 (08/13/77)	0.55	1427.29	11
1976	1427.74 (04/27/76)	1426.39 (10/08/76)	1.35	1426.98	21
1975	1428.44 (07/03/75)	1427.54 (09/12/75)	0.90	1428.04	15
1974	1428.49 (06/07/74)	1427.23 (11/02/74)	1.26	1428.02	20
1973	1427.72 (04/25/73)	1427.72 (04/25/73)		1427.72	1
1972	1428.04 (08/25/72)	1427.48 (08/04/72)	0.56	1427.71	19

Period of Record 05/26/72 - 09/25/89
Datum adjustment 1929

Total number of Readings: 127
Highest Recorded: 1428.49 (06/07/74)
Lowest Recorded: 1426.39 (10/08/76)
Range All Readings: 2.10
Mean All Readings: 1427.61

Historic Water Levels for Lake: Little Sand, Hubbard County, #290150



Period of Record: 05/26/72-09/25/89, 18 years

F7

APPENDIX F. 1989 SECCHI MEASUREMENTS FOR THE ALBERG SITE AND FOR LAKE IDA.