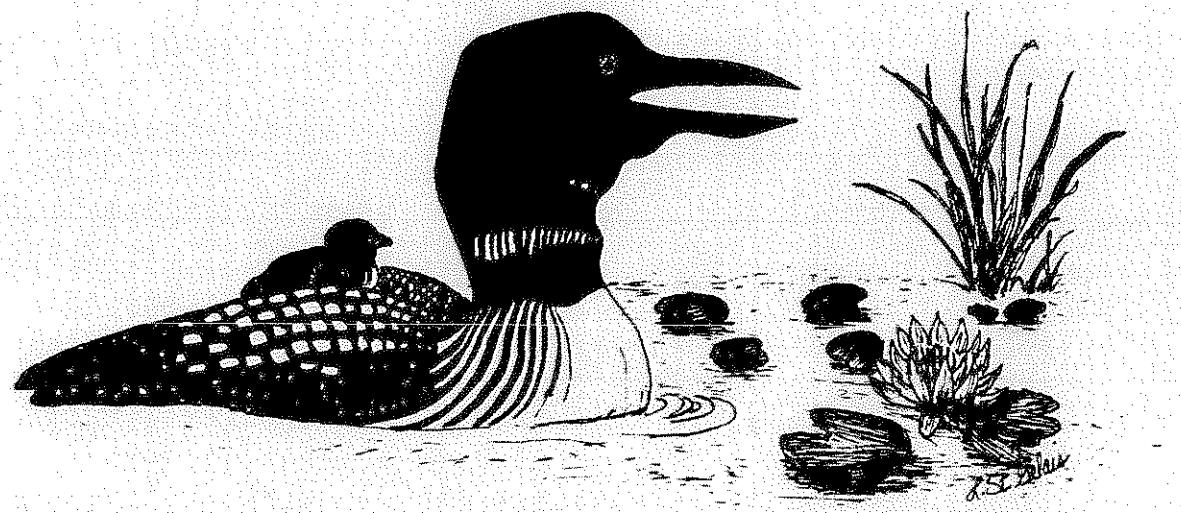
# NATICOOK LAKE

## Water Quality Monitoring: 1996
## Summary and Recommendations

## NH LAKES LAY MONITORING PROGRAM




by
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&
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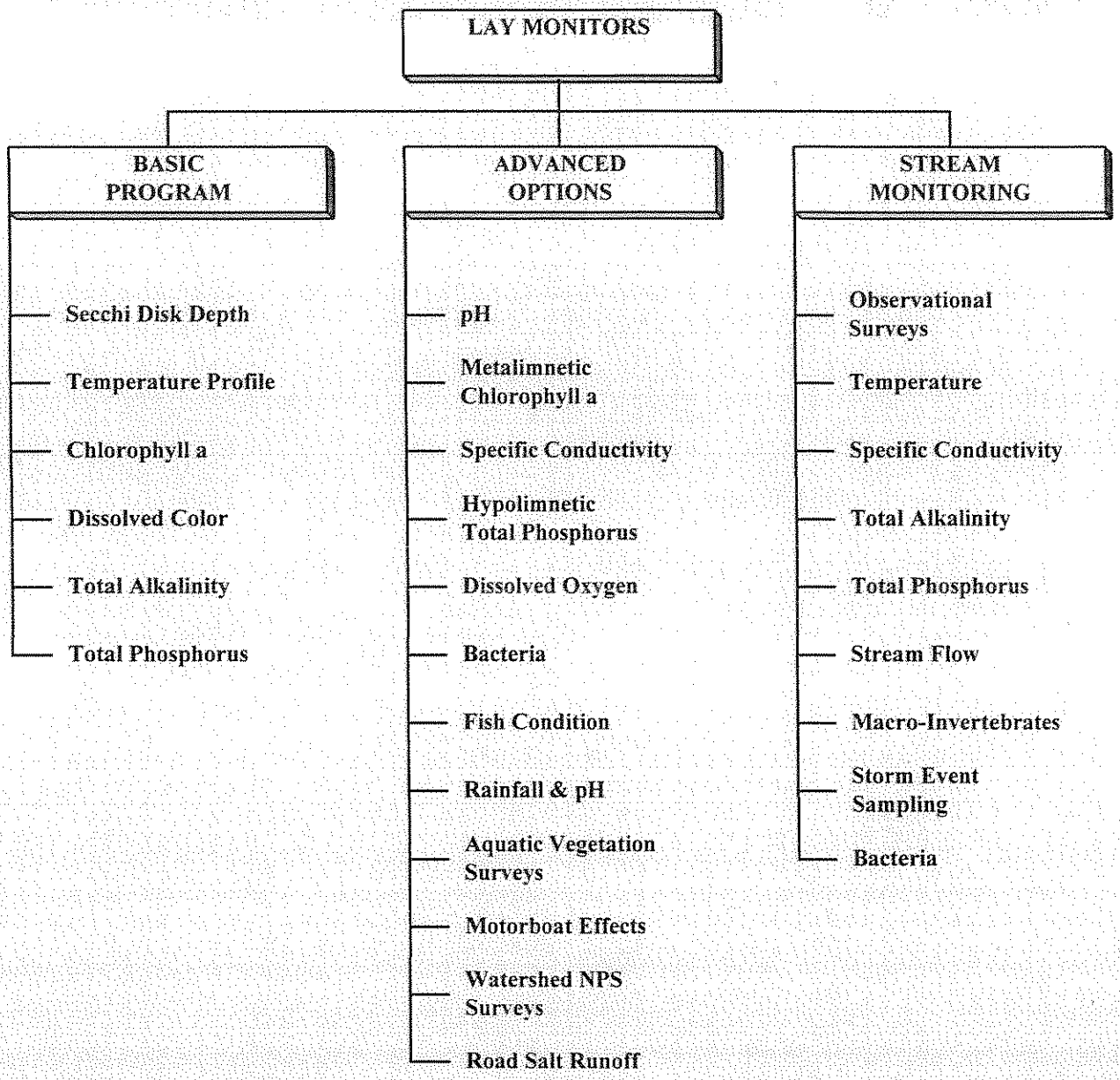
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UNIVERSITY OF NEW HAMPSHIRE COOPERATIVE EXTENSION


To obtain more information about the NH Lakes Lay Monitoring Program (NH LLMP) contact the Coordinator (Jeff Schloss) at (603) 862-3848, Bob Craycraft (603) 862-3546, Dr. Alan Baker (603) 862-3845 or Dr. James Haney (603) 862-2105.

# PARAMETERS SAMPLED

## NH LAKES LAY MONITORING PROGRAM




Freshwater Biology Group (FBG) corroboration with the lay monitor data includes assessment of 1) physical parameters (water transparency, temperature profiles, light transmission profiles and water color); 2) chemical parameters (dissolved oxygen profiles, "free" carbon dioxide, total alkalinity, pH, total phosphorus and specific conductivity profiles); 3) biological parameters (chlorophyll a, phytoplankton community and zooplankton community). Note: in addition to the above parameters, other measurements are often collected at the discretion of the FBG or at the request of the lake association.

# PREFACE

This report contains the findings of a water quality survey of Naticook Lake, Merrimack New Hampshire, conducted in the summer of 1996 by the University of New Hampshire **Freshwater Biology Group** (**FBG**) and the Naticook Lake Association.

The report is written with the concerned lake resident in mind and contains a brief, non-technical summary of 1996 results as well as more detailed "Introduction" and "Discussion" sections. Graphic display of data is included, in addition to listings of data in appendices, to aid visual perspective.

# ACKNOWLEDGMENTS

1996 was the fourteenth year Naticook Lake participated in the **New Hampshire Lakes Lay Monitoring Program (LLMP)**. The volunteer monitors involved in the water quality monitoring effort are highlighted in Table 1 while Laura Jaynes also coordinated the volunteer monitoring activities on Naticook Lake and acted as liaison to the **Freshwater Biology Group**. **The Freshwater Biology Group** congratulates the volunteer monitors on the quality of their work, and the time and effort put forth. We invite other interested residents to join Naticook Lake water quality monitoring effort in 1997 and expand upon the current data base. Funding for the volunteer monitoring effort was provided by the Town of Merrimack (through the conservation commission).

**Table 1: Naticook Lake Volunteer Monitors (1996)**

| Monitor Name |
|---|
| Kathleen Cross |
| Julie Jaynes |
| Laura Jaynes |
| Steve Jaynes |

The **Freshwater Biology Group** is a not-for-profit research program co-supervised by Dr. Alan Baker and Dr. James Haney and coordinated by Jeffrey Schloss. Members of the **FBG** summer field team included, Robert Craycraft (laboratory and field team coordinator), Laura Boddington, Steve Paulding, Steve Tobin and Alex Wong while Shawna Durley and Michelle Hermon provided additional support in the fall. We also acknowledge Nancy Lambert for her assistance in generating digital maps for participating **NH LLMP** lakes.

The **FBG** acknowledges the University of New Hampshire Cooperative Extension for funding and furnishing office, laboratory and storage space. The College of Life Sciences and Agriculture provided accounting support and the UNH Office of Computer Services provided computer time and data storage allocations.

Participating groups in the **LLMP** include: The Center Harbor Bay Conservation Commission, Dublin Garden Club, Eaton Conservation Commission, Governor's Island Club Inc., Laconia Conservation Commission, Meredith Bay Rotary Club, The New Hampshire Audubon Society, North River Lake Water Quality Audit Committee, Society for Protection of Lakes and Streams, Walker's Pond Conservation Society, United Associations of Alton, the associations of Baboosic Lake, Berry Bay, Bow Lake Camp Owners, Chalk Pond, Lake Chocorua, Cunningham Pond, Crystal Lake, Dublin Lake, Goose Pond, Great East Lake, Lake Kanasatka Watershed, Langdon Cove, Long Island Landowners, Lovell Lake, March's Pond, Mendum's Pond, Merrymeeting Lake, Milton Ponds Lake Lay Monitoring, Mirror Lake (Tuftonboro), Moultonborough Bay, Lake Winnipesaukee, Naticook Lake, Newfound Lake, Nippo Lake, Pemaquid Watershed, Silver Lake (Madison), Silver Lake (Tilton), Squam Lakes, Sunset Lake, Wentworth Lake and the towns of Alton, Amherst, Enfield, Errol, Madison, Meredith, Merrimack, Milan, Strafford and Wolfeboro.

# NATICOOK LAKE

# 1996 NON-TECHNICAL SUMMARY

Water quality data were collected by the Naticook Lake volunteer monitors between June 23 and September 29, 1996 while supplemental water quality data were collected by the **Freshwater Biology Group** (August 13, 1996) to augment the volunteer monitor data and provide a more complete assessment of Naticook Lake. *Refer to Appendix A for a complete data listing.* The following section summarizes the 1996 Naticook Lake water quality data and when applicable, incorporates historical data into the interpretation. *Refer to Table 2 for a quick water quality data summary.*

**Table 2: 1996 Naticook Lake (Site 1 Deep) Water Quality Summary Table and the classification criteria employed by the New Hampshire Lakes Lay Monitoring Program.**

| Parameter | Oligotrophic "pristine" | Mesotrophic "transitional" | Eutrophic "enriched" | Naticook Lake Seasonal Avg. |
|---|---|---|---|---|
| Water Clarity (meters) | >4.0 | 2.5 - 4.0 | <2.5 | 3.1 # |
| Chlorophyll a (ppb) | <3.0 | 3.0 - 7.0 | >7.0 | 2.7 # |
| Total Phosphorus (ppb) | <15.0 | 15.0 - 25.0 | > 25.0 | 8.5 * |
| Dissolved Oxygen (mg/l) | > 5.0 | 1.0 - 5.0 | < 1.0 | insufficient data |

# denotes data collected by the volunteer monitor
* denotes data collected by the Freshwater Biology Group

1) The 1996 Naticook Lake water clarity (Secchi Disk transparency) measurements were moderate to high (range: 2.5 to 3.5 meters) and averaged 3.1 meters (10.2 feet). Transparency values greater than 4 meters are typical of a clear, unproductive, lake while transparency values less than 2.5 meters are generally an indication of a highly productive lake (Table 2). Secchi Disk readings between 2.5 and 4.0 meters are considered indicative of a moderately productive lake.

The 1996 Naticook Lake, Site 1 Deep, seasonal average Secchi Disk transparency is near the historical seasonal average Secchi Disk minimum (2.7 meters) documented in 1994 and is below the seasonal average Secchi Disk transparencies documented between 1983 and 1993; range 3.3 to 5.0 meters (Figure 15).

2) The 1996 seasonal average Naticook Lake microscopic plant "algal" concentration (measured as chlorophyll *a*) was low and averaged 2.7 milligrams per cubic meter; mg $m^3$ (range: 1.3 to 4.6 mg $m^3$) at Site 1 Deep. Chlorophyll *a* concentrations below 3 mg $m^3$ are common to an unproductive lake while chlorophyll *a* concentrations above 7 mg $m^3$ are common to a productive lake (Table 2). Chlorophyll *a* concentrations between 3 mg $m^3$ and 7 mg $m^3$ are considered characteristic of a moderately productive lake.

The 1996 seasonal average Naticook Lake, Site 1 Deep, chlorophyll *a* concentration increased relative to the seasonal average chlorophyll *a* concentrations documented

between 1992 and 1995 (1.8 - 2.6 mg $m^3$) but remained well within the range of historical values documented between 1983 and 1995; range: 1.5 to 4.8 mg $m^3$ (Figure 16).

3) The 1996 Naticook Lake seasonal average dissolved lakewater color concentration, 20.7 platinate color units (ptu), was moderate but lower than the seasonal average of 27.1 ptu for **LLMP** lakes. Dissolved color, or true color as it is sometimes called, is indicative of dissolved organic carbon levels in the water (a by-product of microbial decomposition). Small increases in water color from the natural breakdown of plant materials in and around a lake are not considered to be detrimental to water quality. However, increased color can lower water transparency, and hence, change the public perception of water quality. Large amounts of dissolved color might occur naturally but can also occur during deforestation and development within the watershed. High color levels can actually mask the ability of the Secchi Disk transparency to predict chlorophyll levels. Dissolved color data collected by the **NH LLMP** volunteer monitors over the past ten years indicate dissolved color concentrations are typically higher during wet years (years with above average precipitation), when precipitation events flush a large volume of highly colored water into the lake. Lakes surrounded by substantial wetlands (characterized by "tea" colored waters) tend to naturally exhibit large increases in colored waters during wet years. While some might perceive the "tea" colored waters associated with wetlands as a water quality perturbation, one must remember that these wetlands are an integral component to natures filtration system, removing pollutants and purifying the water before it reaches the lake.

4) Total phosphorus (generally considered the limiting nutrient for plant growth in freshwater systems) concentrations, measured in the surface waters of the deep Naticook Lake sampling station, Site 1 Deep, were low in 1996 (range: 5.5 to 11.3 parts per billion; ppb). Total phosphorus concentrations less than 15 ppb are considered typical of unproductive lakes while total phosphorus concentrations greater than 25 ppb are considered typical of highly productive lakes (Table 2). Total phosphorus concentrations between 15 ppb and 25 ppb are common to moderately productive lakes. Supplemental total phosphorus samples, collected by the **Freshwater Biology Group** (August 13, 1996), exhibited a trend of increasing total phosphorus concentrations towards the lakebottom. The total phosphorus concentration increased from 11.3 ppb in the surface waters to 17.3 ppb at 5 meters depth. Higher total phosphorus concentrations near the lakebottom often indicate internal nutrient loading (when nutrients are "released" from the bottom sediments) and are commonly associated with low dissolved oxygen concentrations near the lakebottom.

Additional total phosphorus concentrations collected at selected near-shore locations were low (range: 5.8 to 12.5 ppb) when measured on July 14, August 13 and September 29, with the exception of high total phosphorus concentrations documented at Site 3 Natick; 46.6 ppb on July 14, 1996 and 114.7 ppb on September 29, 1996. *Refer to Figure 11 for sampling locations.*

5) The 1996 Naticook Lake alkalinity (a measure of the lake's resistance to acidification) was moderate, 14.3 milligrams per liter (mg/l), and about 8 units higher than the average of 6.4 mg/l for **LLMP** program lakes. The 1996 Naticook Lake alkalinity was high for a New Hampshire Lake and remained sufficient to buffer against acid precipitation. Supplemental pH data collected by the **Freshwater Biology Group**

(August 13, 1996) measured 7.0 units in the surface waters which is well within the tolerable range for most aquatic organisms.

6) Dissolved salt levels (measured as specific conductivity) were high when measured in Naticook Lake by the **Freshwater Biology Group**. The Specific Conductivity data collected on August 13, 1996 ranged from 214.5 to 224.5 micro-Siemans; *u*S. High conductivity levels can be an indication of problem areas within the watershed where road salt runoff, excessive fertilizer applications, failing septic systems and other human activities are generating "excessive" pollutants which make their way into the lake. Historical data collected by the New Hampshire Department of Environmental Services in 1979, 1989 and 1990 indicate road salt runoff contributes to the high conductivity levels documented in Naticook Lake.

7) Temperature profiles collected by the volunteer monitors indicate the upper mixed layer of water (**epilimnion**) extended down to about 3.5 meters during the summer months. The development of temperature stratification limits circulation within the water column and can favor low dissolved oxygen concentrations in the deeper waters. Dissolved oxygen data collected by the **Freshwater Biology Group** on August 13, 1996 indicate the dissolved oxygen concentrations remained above 3 milligrams per liter (generally considered the minimum oxygen requirement for the successful growth and reproduction of most warmwater fish) only down to about 4.5 meters (Figure 17). Decreasing dissolved oxygen concentrations in the bottom waters suggest the accumulation of organic matter from both internal (i.e. plant and algal growth) and external (i.e. grass clippings and leaf litter) sources. As dissolved oxygen concentrations become depleted, chemical reactions convert previously insoluble "bound" nutrients into a soluble form. The nutrients can then be utilized by algal cells and under adverse conditions result in algal blooms.

8) Based on the current and historical water quality data, Naticook Lake would be considered a moderately productive "transitional" New Hampshire lake. While the chlorophyll *a* and Secchi Disk measurements often fall within the range considered indicative of an unproductive lake, short-term water quality reductions (reduced Secchi Disk transparencies and increased chlorophyll *a* concentrations), particularly during periods of lake mixing, suggest Naticook Lake is better characterized as a moderately productive lake. The low dissolved oxygen concentrations near the lakebottom are a further indication that Naticook Lake is best characterized as a moderately productive "transitional" lake.

# COMMENTS AND RECOMMENDATIONS

1) We recommend that each participating association, including the Naticook Lake Association, continue to develop it's data base on lake water quality through continuation of the long-term monitoring program. The data base currently provides information on the short and long-term cyclic variability that occurs in Naticook Lake and through continued monitoring will enable more reliable predictions of water quality trends.

2) We recommend continued lake sampling early in the season (April/May) to document Naticook Lake's reaction to the nutrient and acid loadings that typically occur during and after spring thaw. Sampling should include alkalinity, chlorophyll *a*, dissolved color and Secchi Disk transparency measurements. Phosphorus samples are also recommended from both the in-lake and the tributary sampling sites. *When tributary samples are collected, streamflow measurements should be included. Streamflow data are used to calculate the phosphorus load originating from the respective tributaries and will help discern the more impacted sub-watersheds around Naticook Lake.*

3) Frequent "weekly" water quality samples, necessary to assess the current condition of Naticook Lake, should continue to be collected whenever possible. Water quality sampling should focus on tributary inlets where pollutants are channelized into the lake, as well as, other suspect nearshore locations where problems might exist *(contact Bob Craycraft for further information at 862-3546)*. A more extensive watershed survey (discussed below) would be useful in identifying and prioritizing regions within the watershed where corrective and educational efforts should be focused. It is imperative that the watershed residents are well educated on water quality related issues if future problems are to be averted. Numerous publications are available through University of New Hampshire Cooperative Extension, the New Hampshire Lakes Association, the New Hampshire Department of Environmental Services, as well as, other local, state and federal agencies. Refer to the section "Understanding Lake Aging (Eutrophication)" for a brief listing of some of the more useful water quality references available and to Appendix B for a review of the New Hampshire Shoreland Protection Act.

4) Changing land use within the Naticook Lake watershed, the surrounding land that drains into the lake, can accelerate the natural aging process (what is known as eutrophication). A typical lake fills in and becomes more productive (i.e. greener) on a geological time frame (thousands of years). However, this process can be accelerated and occur in tens of years when development, agriculture and other landscape changes occur that do not incorporate best management practices (i.e. maintaining vegetative buffer strips along the shoreline, minimizing fertilizer and pesticide applications, installing proper erosion control structures, etc.) that are set up to minimize water quality impacts. We invite interested persons to take part in a new assessment manual, produced jointly by the **NH LLMP** and the U S Natural Resource Conservation Service **(US NRCS)**, which provides the layperson with a systematic method for recognizing and evaluating erosion, sedimentation and related non-point source (NPS) pollutant problems in New Hampshire watersheds. Contact *Jeff Schloss (862-3848)* for further information.

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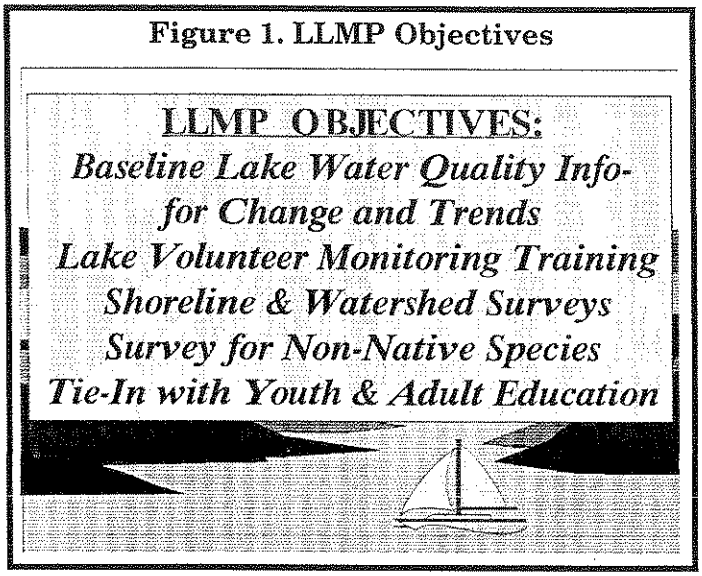
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# INTRODUCTION

## The New Hampshire Lakes Lay Monitoring Program

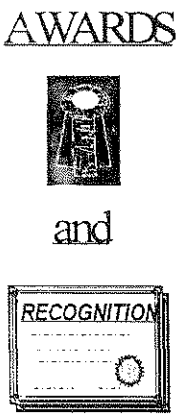
1996 marked the nineteenth year of operation for the **NH Lakes Lay Monitoring Program (LLMP).** The **LLMP** has grown from a university class project on Chocorua Lake and pilot study on the Squam Lakes to a comprehensive state-wide program with over 500 volunteer monitors and more than 100 lakes participating. Originally developed to establish a data-base for determining long-term trends of lake water quality for science and management, the program has expanded by taking advantage of the many resources that citizen monitors can provide (Figure 1).

**Figure 1. LLMP Objectives**




The **NH LLMP** has an international reputation as a successful cooperative monitoring, education and research program. Current projects include: use of volunteer generated data for non-point pollution studies using high tech analysis system (Geographic Information Systems and Satellite Remote Sensing), intensive watershed monitoring for the development of lake nutrient budgets, and investigations of water quality and indicator organisms (food web analysis, fish condition, and stream invertebrates). The key ingredients responsible for the success of the program include innovative costshare funding and cost reduction, assurance of credible data, practical sampling protocols and, most importantly, the interest and motivation of our volunteer monitors.

**Figure 2. Awards & Recognition**



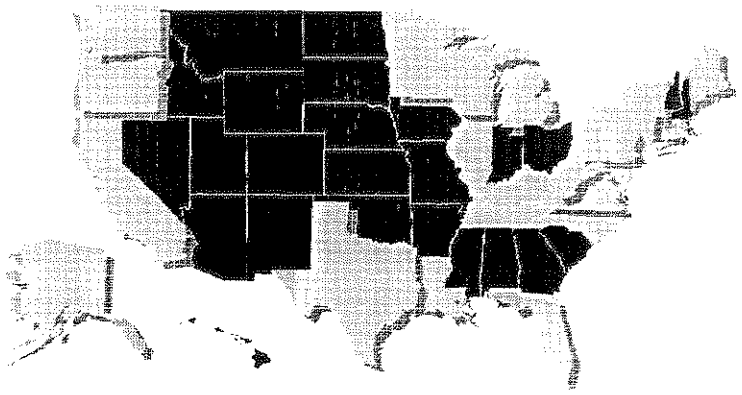

1983- N H Environmental Law Council
1984- Governor's Volunteerism Award
1985- CNN Science & Technology Today
1988- Governor's "Gift" request funded
1990- New Hampshire Journal
1991- Renew America Success Award
Environmental Success Index
UN Environmental Programme
Soviet Embassy Reception
White House Environment Breifing
1992- EPA Administrators Award
Environmental Exchange Network
1993- NH Lakes Association
1994- Fourth National Citizens' Volunteer Monitoring Conference
EPA Office of Watersheds Award
1995- Co-editors Volunteer Monitor Newsletter (Spring Issue)
Winnipesaukee Watershed Project
1996 - Fifth National Citizens' Volunteer Monitoring Conference

The 1996 sampling season was another exciting year for the **New Hampshire Lakes Lay Monitoring Program**. National recognition for the high quality of

work by you, the volunteer monitors, continued with awards, requests for program information and invitations to speak at national conferences (Figure 2).

**Figure 3. National LLMP Support to Volunteer Monitoring Programs**

NH LLMP Directly inolved with the Initiation, Expansion or Support of Volunteer Programs in 24 States.



Light gray shading denotes LLMP assisted states

Our work with volunteer monitors, data analysis, use of Geographic Information System technology and our new watershed evaluation system for non-point source pollution ("Following the Flow") was presented at meetings and conferences across the country including the prestigious Watershed '96 Conference in Baltimore, Maryland, the Sixth National Citizen's Environmental Monitoring Conference in Wisconsin, the Gulf of Maine Monitoring Conference, the Merrimack River Monitoring Network Conference and the North American Lake Management Society's Annual International Symposium in Minnesota. We also hosted a group of coordinators of the Australian and Tasmanian StreamWatch Programs who were interested in our sampling methods and the "Following the Flow" site evaluation system. They toured Bow Lake with monitor Jim McCarthy and even saw some loons, an Aussie first! We expanded our monitoring on Lake Winnipesaukee as a result of our analysis completed last year for the Lakes Region Planning Commission and helped to train Americorp volunteers on how to assist local residents with watershed protection concerns.

On the local front, the NH Senate Agricultural and Environment committee and the NH House Resource, Recreation and Development Committee were again briefed on **NH LLMP** activities. We continue to be listed as a model citizen monitoring program on the Environmental Success Index of Renew America, the Environmental Network Clearinghouse and the National Awards Council for Environmental Sustainability To date, the approach and methods of the **NH LLMP** have been adopted by new or existing programs in twenty four states and eleven countries (Figure 3)!

## Importance of Long-term Monitoring

A major goal of our monitoring program is to identify any short or long-term changes in the water quality of the lake. Of major concern is the detection of cultural eutrophication: increases in the productivity of the lake, the amount of algae and plant growth, due to the addition of nutrients from human activities. Changes in the natural buffering capacity of the lakes in the program is also a topic of great concern, as New

Hampshire receives large amounts of acid precipitation, yet most of our lakes contain little mineral content to neutralize this type of pollution.

For almost two decades, weekly data collected from lakes participating in the **New Hampshire Lakes Lay Monitoring Program** have indicated there is quite a variation in water quality indicators through the open water season (April through November) on the majority of lakes. Short-term differences may be due to variations in weather, lake use, or other chance events. Monthly sampling of a lake during a single summer provides some useful information, but there is a greater chance that important short-term events such as algal blooms or the lake's response to storm run-off will be missed. These short-term fluctuations may be unrelated to the actual long-term trend of a lake or they may be indicative of the changing status or "health" of a lake.

**Figure 4.**

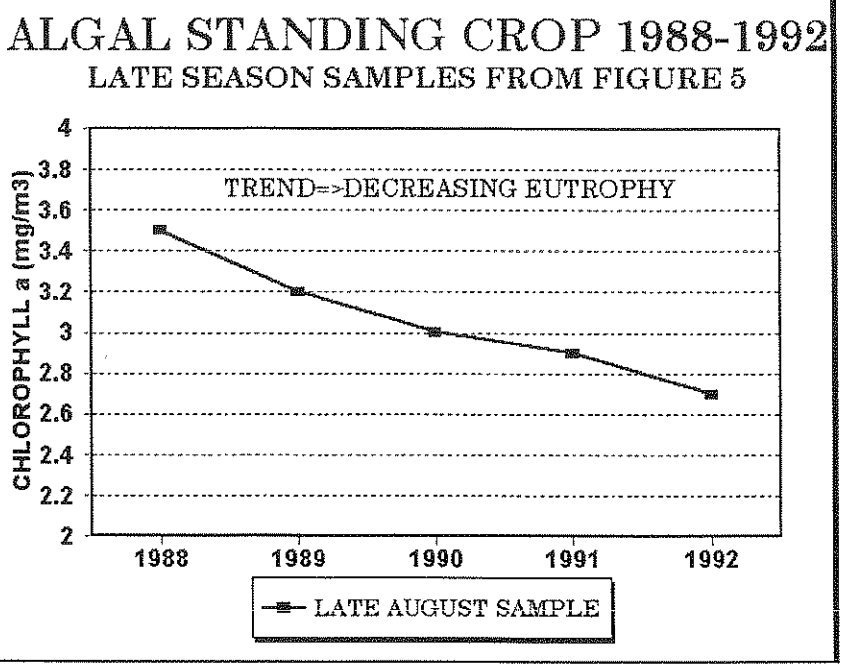
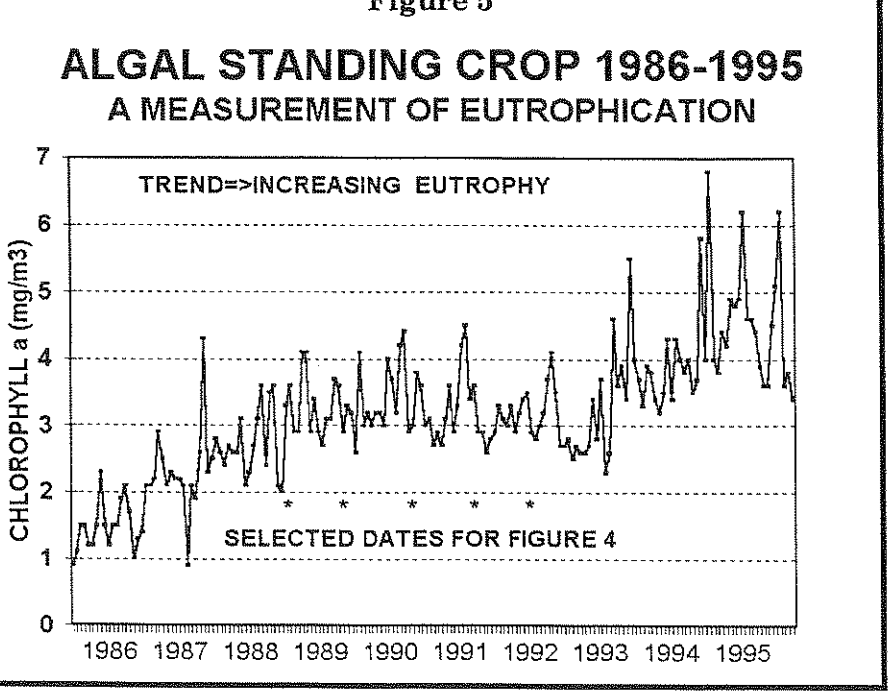



**Figure 5**




Consider the hypothetical data depicted in Figure 4. Sampling only once a year during August from 1988 to 1992 produced a plot suggesting a decrease in eutrophication. However, the actual long-term term trend of the lake, increasing eutrophy, can only be clearly discerned by frequent sampling over a ten year period (Figure 5). In this instance, the information necessary to distinguish between short-term fluctuations "noise" and long-term trends "signal" could only be ac-

complished through the frequent collection of water quality data over many years. To that end, the establishment of a long term database was essential to trend detection.

The number of seasons it takes to distinguish between the noise and the signal is not the same for each lake. Evaluation and interpretation of a long-term data base will indicate that the water quality of the lake has worsened, improved, or remained the same. In addition, different areas of a lake may show a different response. As more data are collected, prediction of current and future trends can be made. No matter what the outcome, this information is essential for the intelligent management of your lake.

There are also short-term uses for lay monitoring data. The examination of different stations in a lake can disclose the location of specific problems and corrective action can be initiated to handle the situation before it becomes more serious. On a lighter note, some associations post their weekly data for use in determining the best depths for finding fish!

It takes a considerable amount of effort as well as a deep concern for one's lake to be a volunteer in the **NH Lakes Lay Monitoring Program**. Many times a monitor has to brave inclement weather or heavy boat traffic to collect samples. Sometimes it even may seem that one week's data is just the same as the next week's data. Yet every sampling provides important information on the variability of the lake.

We are pleased with the interest and commitment of our Lay Monitors and are proud that their work is what makes the **NH LLMP** the most extensive, and we believe, the best volunteer program of its kind.

## Purpose and Scope of This Study

1996 was the fourteenth year that water quality monitoring of Naticook Lake was undertaken by the **Freshwater Biology Group** and the Naticook Lake Association. The monitoring program was designed to continue adding data to the long-term data base established. Sampling emphasis was placed on one open water deep sampling station, Site 1 Deep, while supplemental near-shore samples were also collected (Figure 11).

The primary purpose of this report is to discuss results of the 1996 monitoring season with emphasis on current conditions of Naticook Lake including the extent of eutrophication and the lake's susceptibility to increasing acid precipitation. This information is part of a large data base of historical and more recent data compiled and entered onto computer files for New Hampshire lakes that include New Hampshire Fish and Game surveys of the 1930's, the surveys conducted by the New Hampshire Water Supply and Pollution Control Commission and the **FBG** surveys. However, care must be taken when comparing current results with early studies. Many complications arise due to methodological differences of the various analytical facilities and technological improvements in testing.

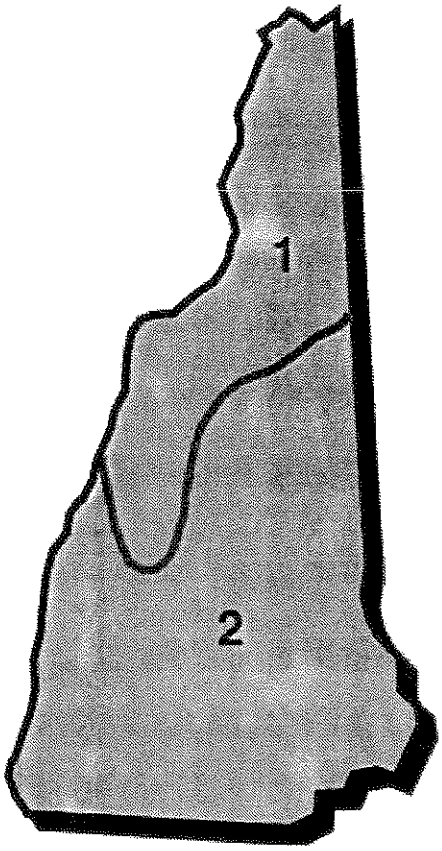
# The General Scenario - 1996

## 1996 Climatic Summary

### Precipitation

The winter months of 1995-1996 were characterized by above average precipitation in southern New Hampshire (Figure 6). The "Blizzard of '96" (January 6-8) blanketed the Southern region of the state with up to 17" of snow. February precipitation levels were high at times but were near the historical norm when averaged for the month while March precipitation levels were approximately 1" below the historical average (Figure 7).

**Figure 6. Regional New Hampshire Climatological Breakdown (Northern #1 vs Southern #2 New Hampshire).**




The spring months of April and May were again characterized by above average precipitation that exceeded the historical average and translated into heavy runoff periods. June kicked off the summer with below average precipitation levels while July was an extremely wet month (over 3" above the historical average). August was by far the driest month of the year (0.56") and set a record for minimal rainfall during the month. The remainder of the year oscillated between months slightly below the historical average (September and November) to months characterized by precipitation levels well above the historical average (October and December). The total 1996 precipitation level was near the historical maximum for southern New Hampshire and translated into high groundwater levels and periods of heavy runoff into our New Hampshire lakes and ponds.

A comparison of precipitation data collected in 1995 and 1996 exemplifies the monthly and seasonal variability characteristic of the climatologi-

cal data (Figures 7-8). The 1996 regional Southern New Hampshire seasonal average precipitation level (52.88") was well above the historical seasonal average precipitation level of 41.79 inches (1895-1996) and had a profound effect on water quality for the participating **NH LLMP** lakes (discussed later in this section).

**Figure 7.**

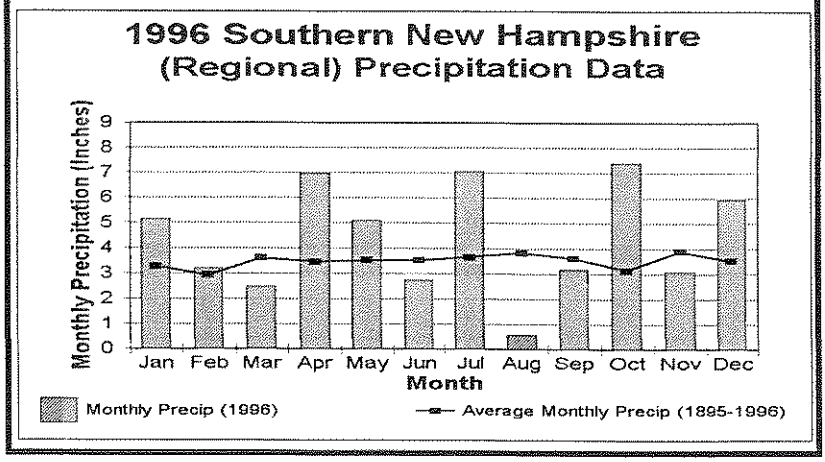



**Figure 8.**

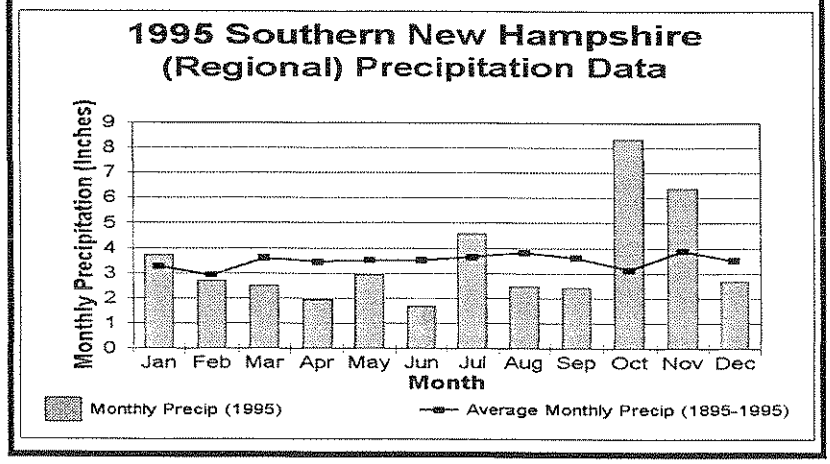
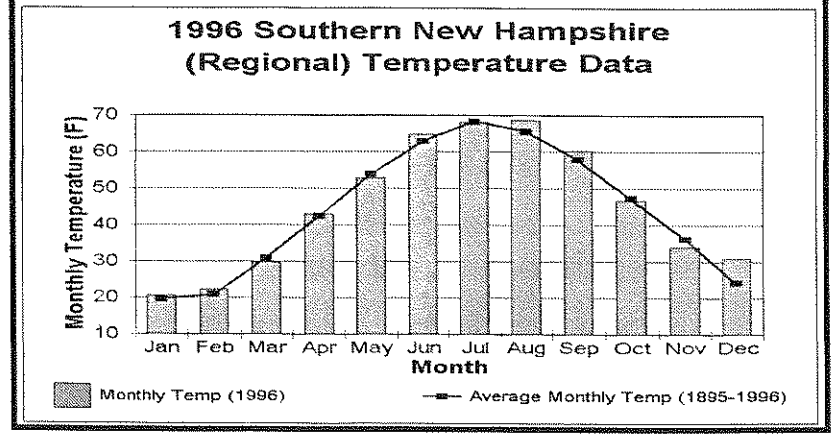



**Figure 9.**




**Temperature**

The 1996 temperature patterns also had an effect on water quality. Average monthly temperatures were near normal for most of the year while deviations from the historical Southern New Hampshire monthly averages were most evident during the months of August, September and December when the monthly averages were well above historical levels and the month of November when the temperatures were well below normal (Figure 9). While the 1996 southern New Hampshire monthly temperature averages were generally characteristic of the historical levels, short term (daily) temperature extremes tended to characterize the year as exemplified by the atypically high January temperatures which reached 61°F in southern New Hampshire and translated into a heavy midwinter thaw at that time. The daily ambient temperatures tended to display a 'seesaw' pattern of temperatures. Extremely cold conditions (such as those encountered in early February) were often followed by unusually warm periods. Thus, the monthly temperature summaries give a rough estimate of the month's temperature patterns.

## 1996 Water Quality Observations

### Water Clarity

The precipitation patterns characteristic of 1996 favored reduced water clarities, increased dissolved color concentrations, increased nutrient concentrations and increased algal concentrations in our New Hampshire lakes. Heavy periods of watershed runoff often coincide with elevated nutrient levels conducive to algal growth. Watershed runoff also favors the flushing of sediments into the lake, particularly during periods of heavy runoff and when protective vegetative buffers are reduced or absent. Vegetative buffers are naturally reduced in the early spring before plants recolonize and before leaves grow out. Vegetative buffers can be more permanently reduced during periods of construction and logging throughout the year.

While precipitation levels generally favored poorer water quality (in terms of increased algal growth, increases in nutrient concentrations and water clarity decreases) the temperatures characteristic of 1996 were not highly conducive of algal and macroscopic plant growth as they were in 1994 and 1995 when above average temperatures favored excessive vegetative growth around the periphery of our lakes and ponds. Thus, while the heavy precipitation levels reduced our water quality, the near average monthly temperatures through most of the year tended to keep microscopic plant "algal" and aquatic weed growth "in-check" (aquatic plant growth in our New Hampshire lakes tends to increase as temperatures increase).

Shallower Secchi Disk transparency readings, relative to 1995, were characteristic of most New Hampshire lakes during the 1996 sampling season. Deep lake sampling stations were less clear due to a combination of factors associated with the atypically wet year. Greater concentrations of dissolved colored compounds (dissolved organic matter resulting from the breakdown of vegetation and soils) were washed in from surrounding forests and wetlands. Dissolved water color is not indicative of water quality problems (although large increases in dissolved color sometimes follow large land clearing operations) but in some of our more pristine program lakes, it nevertheless has a large effect on water clarity changes.

Sediments were flushed into our lakes and ponds during periods of heavy watershed runoff, particularly early in the season and again during and following sporadic storm events during the summer and fall months. Many New Hampshire lakes experienced water clarity decreases following storm events such as those described above. Lakes, ponds and rivers are particularly susceptible to sediment loadings in the early spring months when vegetated shoreside buffers, often referred to as riparian buffers, are reduced. With limited vegetation to trap sediments and suspended materials, a high percentage of the watershed runoff gets into the lake. Other activities such as logging, agriculture, construction and other forms of soil disturbance can also increase sediment displacement during and following heavy storm events throughout the year and were the likely culprits of excessive sediment loading in many of our lakes and ponds. As these materials (sediments) are transported into a receiving water they can degrade water quality in a number of ways. When fine sediments (silt) enter a lake they tend to remain in the water column for relatively long periods of time. These suspended sediments can be abrasive to fish gills, ultimately leading to fish kills. Suspended sediments also reduce the available light necessary for plant growth which can result in plant die-offs and oxygen depletion under extreme conditions.

As sediments settle out of the water column they can smother bottom dwelling aquatic organisms and smother fish spawning habitat. As the dead materials begin to decay the result could be noxious odors as well as stimulation of nuisance plant growth (i.e. scums along the lakebottom, new macroscopic plant growth). Note: one should keep in mind that nuisance plants such as water millfoil, *Meriophyllum heterophyllum*, will generally regenerate more rapidly than more favorable plant forms and can result in more problematic weed beds than those present before the disturbance. Habitat changes associated with the accumulation of fine sediments and associated "muck" might also favor increased nuisance plant growth in the future. Another un-favorable attribute of sediment loading is that the sediments tend to carry with them other sorts of contaminant such as pathogens, nutrients and other toxic chemicals (i.e. herbicides and pesticides).

Early symptoms of excessive sediment runoff include deposits of fine material along the lakebottom, particularly in close proximity to tributary inlets and disturbed regions previously discussed (i.e. construction sites, logging sites, etc.). Silt may be visible covering rocks or aquatic vegetation along the lakebottom. During periods of heavy overland runoff the water might appear brown and turbid which reflects the sediment load. As material collects along the lakebottom you might notice a change in the weed composition reflecting a change in the substaight type (note: aquatic plants will display natural changes in abundance and distribution, so be careful not to jump to hasty conclusions). If excessive sediment loading is suspected, take a closer look in these areas and assess whether or not the change is associated with sediment loading (look for the warning signs discussed above) or whether the changes might be attributable to some other factor.

**Nutrients**

Nutrient loading tended to be high in 1996, particularly during the periods of heavy watershed runoff. Elevated phosphorus (generally considered the limiting nutrient for excessive plant and algal growth in New Hampshire lakes) concentrations were most visible when documented in our tributary inlets. Much of the phosphorus entering our lakes was complexed with particulate matter (i.e. sediments, vegetative debris), but also included phosphorus associated with fertilizer applications and septic system discharge. While the amount of fertilizers and the integrity of septic systems might not have changed relative to 1995, when water quality was generally high in participating **NH LLMP** lakes, the high groundwater levels associated with the heavy watershed runoff collected and transported nutrients like phosphorus into our lakes and ponds.

**Algal Growth**

If decreased water clarity was not the result of less dissolved color or less algal growth (measured as chlorophyll *a*) than, by default, it was likely due to suspended sediments. To find out how these water quality indicators interrelate for Naticook Lake, Site 1 Deep, compare the Secchi Disk transparency, chlorophyll *a* and dissolved color graphs enclosed in this report (Figures 12 through 14). Note whether changes in water clarity (Secchi Disk transparency) correspond to chlorophyll *a* or dissolved color concentration changes or whether it is a combination of the two. If neither seem to exhibit a consistent effect, then suspended sediment likely plays an important role in your lake's clarity.

Most lakes experienced "algal blooms" during the 1996 sampling season. "Algal blooms" are often "green water events" associated with decreases in water clarity due to their ability to absorb and scatter light within the water column, but can also accumulate near the lake bottom in shallow areas as "mats" or on the water surface as "scums" and "clouds". The 1996 algal blooms were predominantly "green water events" composed of algae distributed within the water column. New Hampshire lakes were particularly susceptible to algal blooms in 1996 as a function of the heavy runoff associated with the atypically wet year. Wet years such as 1996 can be particularly hard on lakes where excessive fertilizer applications, agricultural practices, construction activities, etc. favor the displacement of nutrients into a receiving water. The occasional formation of certain "algal blooms" are naturally occurring phenomena and are not necessarily associated with changes in lake productivity. However, increases in the occurrence of "bloom" conditions can be a sign of eutrophication (the "greening" of a lake). Algal blooms occurred even in our most pristine lakes throughout the 1996 sampling season and in many instances included the presence of nuisance cyanobacterial forms such as *Anabaena*, *Lyngbya*, *Merrismopedia* and *Oscillatoria*.

While the open water appeared greener than previous years, filamentous cotton-candy like "clouds" of the nuisance green filamentous algae, *Mougeotia*, and related species were not well documented in 1996. These algal "clouds" often develop within nearshore weed beds where they can be seen along the lakebottom and tend to flourish during atypically warm periods which warm our surface waters. Unlike 1994 and 1995, when temperatures well above normal in June and July and in-turn stimulated large growths of filamentous algae, 1996 was a mild summer through July which kept this type of algal growth in "check".

In other lakes, metalimnetic algae, algae which tend to grow in a thin layer along the thermocline gradient in a lake's middle depths, sometimes migrate up towards the lake surface causing a "bloom" event. If these algae are predominantly "nuisance" forms, like certain green or blue-green algae, they can be an early indication of nutrient loading. The **LLMP** will continue to monitor "bloom" phenomena in 1997 as they can be a sign of the changing land use practices and impacts within your lake's watershed that can result in a long-term increase in lake productivity (eutrophication). Future monitoring will continue to monitor the frequency of algal blooms in our New Hampshire lakes and discern whether or not they are signs of short-term perturbations in water quality, the "noise" within the true long-term signal, induced by the weather conditions of this past summer. For a limited number of lakes, the 1996 weather patterns resulted in less algal problems and better water quality. Lakes which exhibited improved water quality were generally those lakes which experience what is known as internal nutrient loading (nutrients released from the bottom sediments due to low oxygen concentrations). Internal nutrient loading can be extremely hard on a lake during drier years when the waters stagnate, oxygen is depleted, and the nutrients are not flushed out of the waterbody. Since 1996 was wetter than normal, the flushing of these types of lakes caused higher oxygen levels and less nutrient accumulation in the spring and late fall which in turn reduced the occurrence and magnitude of algal blooms.

# DISCUSSION OF LAKE AND STREAM MONITORING MEASUREMENTS

The section below details the important concepts involved for the various testing procedures used in the **New Hampshire Lakes Lay Monitoring Program**. Where appropriate, summary statistics of 1996 results from all participating lakes are included. Certain tests or sampling performed at the time of the optional **Freshwater Biology Group** field trip are indicated by an asterisk (*).

## Thermal Stratification in the Deep Water Sites

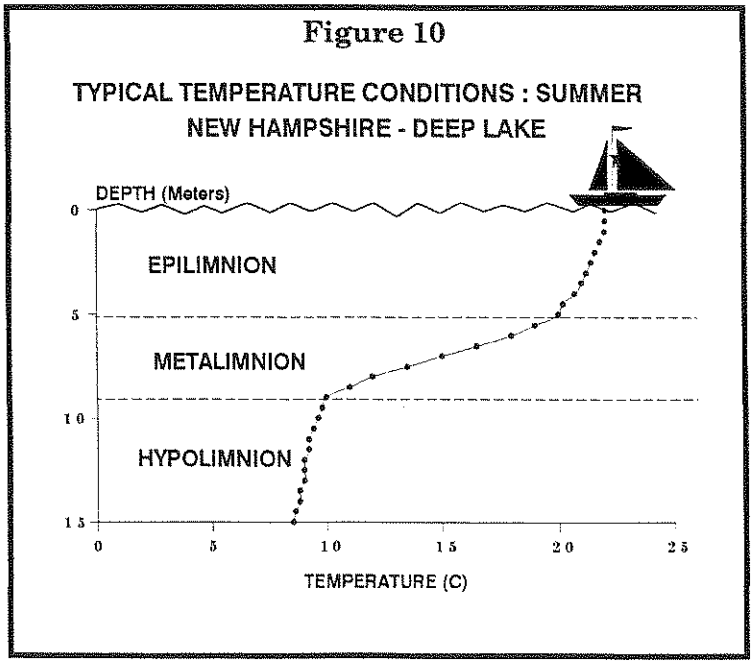
Lakes in New Hampshire display distinct patterns of temperature stratification, that develop as the summer months progress, where a layer of warmer water (the **epilimnion**) overlies a deeper layer of cold water (**hypolimnion**). The layer that separates the two regions characterized by a sharp drop in temperature with depth is called the **thermocline** or **metalimnion** (figure 10). Some shallow lakes may be continually mixed by wind action and will never stratify. Other lakes may only contain a developed epilimnion and metalimnion.

## Water Transparency

Secchi Disk depth is a measure of the water transparency. The deeper the depth of Secchi Disk disappearance, the more transparent the lake water; light penetrates deeper if there is little dissolved and/or particulate matter (which includes both living and non-living particles) to absorb and scatter it.

In the shallow areas of many lakes, the Secchi Disk will hit bottom before it is able to disappear from view (what is referred to as a "Bottom Out" condition). Thus, Secchi Disk measurements are generally taken over the deepest sites of a lake. Transparency values greater than 4 meters are typical of clear, unproductive lakes while transparency values less than 2.5 meters are generally an indication of highly productive lakes. Water transparency values between 2.5 meters and 4 meters are generally considered indicative of moderately productive lakes. The 1996 average transparency for participating **NH LLMP** lakes was 5.4 meters with a range of 1.5 to 14.6 meters.

**Figure 10**



## Chlorophyll *a*

The chlorophyll *a* concentration is a measurement of the standing crop of phytoplankton and is often used to classify lakes into categories of productivity called trophic states. **Eutrophic** lakes are highly productive with large concentrations of algae and aquatic plants due to nutrient enrichment. Characteristics include accumulated organic matter in the lake basin and lower dissolved oxygen in the bottom waters. Summer chlorophyll *a* concentrations average above 7 mg $m^3$ (7 milligrams per cubic meter; 7 parts per billion). **Oligotrophic** lakes have low productivity and low nutrient levels and average summer chlorophyll *a* concentrations that are generally less than 3 mg $m^3$. These lakes generally have cleaner bottoms and high dissolved oxygen levels throughout. **Mesotrophic** lakes are intermediate in productivity with concentrations of chlorophyll *a* generally between 3 mg $m^3$ and 7 mg $m^3$. The 1996 seasonal average chlorophyll *a* concentration for participating NH **LLMP** lakes was 3.1 mg $m^3$ with a range of 0.4 to 22.4 mg $m^3$.

Testing is sometimes done to check for **metalimnetic algal populations**, algae that layer out at the thermocline and generally go undetected if only epilimnetic (point or integrated) sampling is undertaken. Chlorophyll concentrations of a water sample collected in the thermocline is compared to the integrated epilimnetic sample. Greater chlorophyll levels of the point sample, in conjunction with microscopic examination of the samples (see Phytoplankton section below), confirm the presence of such a population of algae. These populations should be monitored as they may be an indication of increased nutrient loading into the lake.

## Turbidity *

Turbidity is a measure of suspended material in the water column such as sediments and planktonic organisms. The greater the turbidity of a given water body the lower the Secchi Disk transparency and the greater the amount of particulate matter present. Turbidity is measured as nephelometric turbidity units (NTU), a standardized method among researchers. Turbidity levels are generally low in New Hampshire reflecting the pristine condition of the majority of our lakes and ponds. Increasing turbidity values can be an indication of increasing lake productivity or can reflect improper land use practices within the watershed which destabilize the surrounding landscape and allow sediment flushing into the lake.

While Secchi Disk measurements will integrate the clarity of the water column from the surface waters down to the depth of disappearance, turbidity measurements are collected at discrete depths from the surface down to the lakebottom. Such discrete sampling can identify layering algal populations (previously discussed) that are undetectable when measuring Secchi Disk transparency alone.

## Dissolved Color

The dissolved color of lakes is generally due to dissolved organic matter from **humic substances**, which are naturally-occurring polyphenolic compounds leached from decayed vegetation. Highly colored or "stained" lakes have a "tea" color. Such substances generally do not threaten water quality except as they diminish sunlight penetration into deep waters. Increases in dissolved watercolor can be an indication of increased development within the watershed as many land clearing ac-

tivities (construction, deforestation, and the resulting increased run-off) add additional organic material to lakes. Natural fluctuations of dissolved color occur when storm events increase drainage from wetlands areas within the watershed. As suspended sediment is a difficult and expensive test to undertake, both dissolved color and chlorophyll information are important when interpreting the Secchi Disk transparency

Dissolved color is measured on a comparative scale that uses standard chloroplatinate dyes and is designated as a color unit or ptu. Lakes with color below 10 ptu are very clear, 10 to 20 ptu are slightly colored, 20 to 40 ptu are lightly tea colored, 40 to 80 ptu are tea colored and greater than 80 ptu indicates highly colored waters. Generally the majority of New Hampshire lakes have color between 20 to 30 ptu. The 1996 seasonal average dissolved color for participating **NH LLMP** lakes was 27.1 ptu with a range of 3.4 to 111.7 ptu.

## Total Phosphorus

Of the two "nutrients" most important to the growth of aquatic plants, nitrogen and phosphorus, it is generally observed that phosphorus is the more limiting to plant growth, and therefore the more important to monitor and control. Phosphorus is generally present in lower concentrations, and its sources arise primarily through human related activity in a watershed. Nitrogen can be fixed from the atmosphere by many bloom-forming blue-green bacteria, and thus it is difficult to control. The total phosphorus includes all dissolved phosphorus as well as phosphorus contained in or adhered to suspended particulates such as sediment and plankton. As little as 10 parts per billion of phosphorus in a lake can cause an algal bloom.

Generally, in the more pristine lakes, phosphorus values are higher after spring melt when the lake receives the majority of runoff from its surrounding watershed. The nutrient is used by the algae and plants which in turn die and sink to the lake bottom causing surface water phosphorus concentrations to decrease as the summer progresses. Lakes with nutrient loading from human activities and sources (Agriculture, Logging, Sediment Erosion, Septic Systems, etc.) will show greater concentrations of nutrients as the summer progresses or after major storm events.

## Streamflow

Streamflow is a measure of the volume of water traversing a given stream stretch over a period of time and is often expressed as cubic meters per second. Knowledge of the streamflow is important when determining the amount of nutrients and other pollutants that enter a lake. Knowledge of the streamflow in conjunction with nutrient concentrations, for instance, will provide the information necessary to calculate phosphorus loading values and will in turn be useful in discerning the more impacted areas within a watershed.

## pH *

The pH is a way of expressing the acidic level of lake water, and is generally measured with an electrical probe sensitive to hydrogen ion activity. The pH scale has a range of 1 (very acidic) to 14 (very "basic" or alkaline) and is logarithmic (i.e.: changes in 1 pH unit reflect a ten times difference in hydrogen ion concentration). Most aquatic organisms tolerate a limited range of pH and most fish species require a pH

of 5.5 or higher for successful growth and reproduction.

## Alkalinity

Alkalinity is a measure of the buffering capacity of the lake water. The higher the value the more acid that can be neutralized. Typically lakes in New Hampshire have low alkalinities due to the absence of carbonates and other natural buffering minerals in the bedrock and soils of lake watersheds.

Decreasing alkalinity over a period of a few years can have serious effects on the lake ecosystem. In a study on an experimental acidified lake in Canada by Schindler, gradual lowering of the pH from 6.8 to 5.0 in an 8-year period resulted in the disappearance of some aquatic species, an increase in nuisance species of algae and a decline in the condition and reproduction rate of fish. During the first year of Schindler's study the pH remained unchanged while the alkalinity declined to 20 percent of the pre-treatment value. The decline in alkalinity was sufficient to trigger the disappearance of zooplankton species, which in turn caused a decline in the "condition" of fish species that fed on the zooplankton.

The analysis of alkalinity employed by the **Freshwater Biology Group** includes use of a dilute titrant allowing an order of magnitude greater sensitivity and precision than the standard method. Two endpoints are recorded during each analysis. The first endpoint (gray color of dye; pH endpoint of 5.1 ) approximates low level alkalinity values, while the second endpoint (pink dye color; pH endpoint of 4.6) approximates the alkalinity values recorded historically, such as NH Fish and Game data, with the methyl-orange endpoint method.

The average alkalinity of lakes throughout New Hampshire is low, approximately 6.5 mg per liter (calcium carbonate alkalinity). When alkalinity falls below 2 mg per liter the pH of waters can greatly fluctuate. Alkalinity levels are most critical in the spring when acid loadings from snowmelt and run-off are high, and many aquatic species are in their early, and most susceptible, stages of their life cycle.

## Specific Conductivity *

The specific conductance of a water sample indicates concentrations of dissolved salts. Leaking septic systems and deicing salt runoff from highways can cause high conductivity values. Fertilizers and other pollutants can also increase the conductivity of the water. Conductivity is measured in micro**mhos** (the opposite of the measurement of resistance **ohms**) per centimeter, more commonly referred to as micro-Siemans (υS).

## Dissolved Oxygen and Free Carbon Dioxide *

Oxygen is an essential component for the survival of aquatic life. Submergent plants and algae take in carbon dioxide and create oxygen through **photosynthesis** by day. **Respiration** by both animals and plants uses up oxygen continually and creates **carbon dioxide**. Dissolved oxygen profiles determine the extent of declining oxygen concentrations in the lower waters. High carbon dioxide values are indicative of low oxygen conditions and accumulating organic matter. For both gases, as the temperature of the water decreases, more gas can be dissolved in the water.

The typical pattern of clear, unproductive lakes is a slight decline in

hypolimnetic oxygen as the summer progresses. Oxygen in the lower waters is important for maintaining a fit, reproducing, cold water fishery. Trout and salmon generally require oxygen concentrations above 5 mg per liter (parts per million) in the cool deep waters. On the other hand, carp and catfish can survive very low oxygen conditions. Oxygen above the lake bottom is important in limiting the release of nutrients from the sediments and minimizing the collection of undecomposed organic matter.

Bacteria, fungi and other **decomposers** in the bottom waters break down organic matter originating from the watershed or generated by the lake. This process uses up oxygen and produces carbon dioxide. In lakes where organic matter accumulation is high, oxygen depletion can occur. In highly stratified eutrophic lakes the entire hypolimnion can remain unoxygenated or **anaerobic** until fall mixing occurs.

The oxygen peaks occurring at surface and mid-lake depths during the day are quite common in many lakes. These characteristic **heterograde oxygen curves** are the result of the large amounts of oxygen, the by-product of photosynthesis, collecting in regions of high algal concentrations. If the peak occurs in the thermocline of the lake, metalimnetic algal populations (discussed above) may be present.

## Underwater Light *

Underwater light available to photosynthetic organisms is measured with an **underwater photometer** which is much like the light meter of a camera (only waterproofed!). The **photic zone** of a lake is the volume of water capable of supporting photosynthesis. It is generally considered to be delineated by the water's surface and the depth that light is reduced to one percent surface iridescence by the absorption and scattering properties of the lake water. The one percent depth is sometimes termed the **compensation depth**. Knowledge of light penetration is important when considering lake productivity and in studies of submerged vegetation. Discontinuity (abrupt changes in the slope) of the profiles could be due to metalimnetic layering of algae or other particulates (discussed above). The underwater photometer allows the investigator to measure light at depths below the Secchi Disk depth to supplement the water clarity information.

## Indicator Bacteria *

Certain disease causing organisms, pathogenic bacteria, viruses and parasites, can be spread through contact with polluted waters. Faulty septic systems, sewer leaks, combined sewer overflows and the illegal dumping of wastes from boats can contribute fecal material containing these pathogens. Typical water testing for pathogens involves the use of detecting coliform bacteria. These bacteria are not usually considered harmful themselves but they are relatively easy to detect and can be screened for quickly. Thus, they make good surrogates for the more difficult to detect pathogens.

**Total coliform** includes all coliform bacteria which arise from the gut of animals or from vegetative materials. **Fecal coliform** are those specific organisms that inhabit the gut of warm blooded animals. Another indicator organism **Fecal streptococcus** (sometimes referred to as **enterococcus**) also can be monitored. The ratio of fecal coliform to fecal strep may be useful in suggesting the type of animal source responsible for the contamina-

tion. In 1991, the State of New Hampshire changed the indicator organism of preference to E. Coli which is a specific type of fecal coliform bacteria thought to be a better indicator of human contamination. The new state standard requires Class A "bathing waters" to be under 88 organisms (referred to as colony forming units; cfu) per 100 milliliters of lakewater.

Ducks and geese are often a common cause of high coliform concentrations at specific lake sites. While waterfowl are important components to the natural and aesthetic qualities of lakes that we all enjoy, it is poor management practice to encourage these birds by feeding them. The lake and surrounding area provides enough healthy and natural food for the birds and feeding them stale bread or crackers does nothing more than import additional nutrients into the lake and allows for increased plant growth. As birds also are a host to the parasite that causes "swimmers itch", waterfowl roosting areas offer a greater chance for infestation to occur. Thus while leaving offerings for our feathered friends is enticing, the results can prove to be detrimental to the lake system and to human health.

## Phytoplankton *

The planktonic community includes microbial organisms that represent diverse life forms, containing photosynthetic as well as non-photosynthetic types, and including bacteria, algae, crustaceans and insect larvae (the insect larvae and zooplankton are discussed below in separate sections). Because planktonic algae or "phytoplankton" tend to undergo rapid seasonal cycles on a time scale of days and weeks, the levels of populations found should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

The composition and concentration of phytoplankton can be indicative of the trophic status of a lake. Seasonal patterns do occur and must be considered. For example **diatoms**, tend to be most abundant in April-June and October-November, in the surface or epilimnetic layers of New Hampshire lakes. As the summer progresses, the dominant types might shift to **green algae** or **golden algae**. By late season **Bluegreen bacteria** generally dominate. In nutrient rich lakes, nuisance green algae and/or bluegreen bacteria might dominate continually. After fall mixing diatoms might again be found to bloom.

## Zooplankton *

There are three groups of zooplankton that are generally prevalent in lakes: the **protozoa**, **rotifers** and **crustaceans**. Most research has been devoted to the last two groups although protozoa may be found in substantial amounts. Of the rotifers and the crustaceans, time and budgetary constraints usually make it necessary to sample only the larger zooplankton (macrozooplankton; larger than 80 or 150 microns; 1 million microns make up a meter). Thus, zooplankton analysis is generally restricted only to the larger crustaceans. Crustacean zooplankton are very sensitive to pollutants and are commonly used to indicate the presence of toxic substances in water. The crustaceans can be divided into two groups, the **cladocerans** (which include the "water fleas") and the **copepods**.

Macrozooplankton are an important component in the lake system. The filter feeding of the herbivorous ("grazing") species may control the population size of selected species of

phytoplankton. The larger zooplankton can be an important food source for juvenile and adult planktivorous fish. All zooplankton play a part in the recycling of nutrients within the lake. Like the phytoplankton, zooplankton, tend to undergo rapid seasonal cycles. Thus, the zooplankton population density and diversity should be considered to be most representative of the time of collection and not necessarily of other times during the ice-free season, especially the early spring and late fall periods.

## Macroinvertebrates *

Macroinvertebrates generally refer to the aquatic insect community living near the bottom substrate (i.e. sediments) while other invertebrate groups such as the crayfish, leeches and the aquatic worms are also included. Like the phytoplankton and zooplankton, previously discussed, the macroinvertebrates undergo seasonal cycles and are most representative of conditions for particular periods of the year. The mayflies are probably the most well known example of a seasonal aquatic macroinvertebrate as mayfly populations metamorphosize into adults as the water temperatures increase in the spring and thus giving rise to the name "mayflies". Macroinvertebrates are also sensitive to environmental conditions such as streamflow, temperature and food availability and are most representative of particular habitats along the stream continuum (i.e. some organisms prefer slower moving stream reaches while others prefer rapidly flowing waters).

Macroinvertebrates are an essential component to a healthy aquatic habitat. Macroinvertebrates help decompose organic matter entering the system such as leaves and twigs and also serve as a food source for many fish species.

While some macroinvertebrates are capable of breathing air as we do, others have gills and utilize oxygen dissolved in the water much as fish do. Macroinvertebrates also vary in their tolerance to depleting dissolved oxygen concentrations making them a good indicator of pollutants coming into the water body. The caddisflies (Trichoptera), the mayflies (Ephemeroptera) and the stoneflies (Plecoptera) are often considered highly sensitive to pollution while the "true" flies (Diptera) are often considered highly tolerant to pollution. However, exceptions to the above categorizations are often encountered.

A variety of indices have been proposed to characterize water bodies over a gradient of pollution levels ranging from least polluted to most polluted scenarios and often designated by assigning a numerical delineator (i.e. 1 is least polluted while 10 is most polluted). Such an index, the Hilsenhoff Biotic Index (HBI), or a modification thereof, is commonly used by stream monitoring programs around the country. Macroinvertebrate data are useful in discerning the more impacted areas within the watershed where corrective efforts should be directed. Unlike chemical measurements that represent ambient conditions in the water body, the macroinvertebrate community composition integrates the water quality conditions over a longer period (months to years) and can identify "hot" spots missed by chemical sampling. If you are interested in more information regarding macroinvertebrate monitoring contact the **LLMP** coordinator.

## Fish Condition

The assessment of fish species "health" is another biological indicator

of water quality. Because fish are at the top of the food chain, their condition should reflect not only water quality changes that affect them directly but also those changes that affect their food supply. The fish condition index utilized by the **New Hampshire Fish Condition Program** is based on two components; fish scale analysis and a fish condition index.

Like tree trunks, fish scales have annual growth rings (annuli) that reflect their growth history and hence, provide a long-term record of past conditions in the lake. The fish condition index, based upon length and weight measurements, is a good indicator of the fish's health at the time of collection.

The resulting fish condition data can be compared among different lakes or among different years, or the index for a particular species can be compared to standard length-to-weight relationships that have been developed by fisheries biologists for many important fish species. In the end, the "health" of the various fish species reflects the overall water quality in the respective lake or pond.

## Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) are non-native, freshwater mollusks. The veligers (larval form) are free swimming, nearly invisible, and profuse. Adult zebra mussel shells are elongate (D-shaped), about the size of a thumbnail and are usually striped. Zebra Mussels are the only freshwater mussel that can attach to objects using sticky threads (byssal threads like those found on the marine blue mussels). These threads allow them to colonize quickly and reach densities of 100,000 or more mussels per square yard. The mussels have an average lifespan of 3.5 to 5 years. A gritty feeling on your boat's hull or other immersed surfaces might indicate that larval zebra mussels have settled.

Zebra mussels originated in the drainage basins of the Black, Caspian, and Aral seas of eastern Europe and have been in western Europe freshwaters since the 1700s. Since first being introduced to North America in 1986, zebra mussels have dramatically altered the balance of freshwater systems and fisheries. These small water dwelling animals have also caused millions of dollars in expenses for industrial water users, drinking water facilities, commercial and recreational boaters, farmers, and other groups and organizations in Canada and the Great Lakes region.

The range occupied by these unwelcome visitors has expanded and continues to grow rapidly. In North America, sightings have been recorded as far north as the Saint Lawrence River near Quebec, as far east as the lower portion of the Hudson River, as far south as the Mississippi River near Vicksburg, and as far west as the Arkansas River in Oklahoma.

In 1993, zebra mussel sightings were confirmed in New England (Lake Champlain). The Lake Champlain population has existed for at least three years, if not longer. Thus, New Hampshire residents and boaters are being encouraged to arm themselves with knowledge about the natural history and geographic spread of the mussels. Interstate boaters and anglers, in particular, should become familiar with boating and fishing practices that decrease the likelihood that zebra mussels will be transferred from an infested water body to an uninfested one.

The infestation risk factor for any particular water body is determined mainly by the amount and type of boat traffic it supports and the chemical characteristics and temperature it

maintains. While the goal is to prevent the mussels from becoming established in New England waters, zebra mussels have proven to be adaptable creatures able to survive in a growing range of environmental conditions. Cooperative monitoring activities coordinated by the **New Hampshire Lakes Lay Monitoring Program** will help determine if and when zebra mussels become established in this region. If zebra mussels are found, information about control techniques can help those concerned choose the best method to reduce the destructive impacts of the mussels.

Take responsibilities for our waters. If you've been boating in fresh water outside of New England within the past 10 days and plan to launch locally, please...

**Inspect** your boat and trailer for weeds. Remove and discard any you find. Zebra mussels are commonly found on aquatic plants in areas of infestation.

**Flush** the cooling system, bilge areas and live wells with tap water.

**Leave** unused bait behind and discard bait bucket water away from surface waters.

**Keep** your boat out of water to dry for 48 hours. If it is visibly fouled by algae, leave it out until the exterior is completely dry **or...**

**Wash** down the hull at a car wash. Hot (140 degree F) water kills zebra mussels and veligers and high pressure spray helps remove them. Wash fouling off your boat away from water sources!

**Learn** more about the zebra mussel threat in order to be forewarned of the situation and prevent costly repairs or destructive responses.

**Share** information, ideas and monitoring tasks with other members of your lake association, watershed council, marina club, conservation commission, angling group or civic organization.

**Report** any sightings to the **New Hampshire Lakes Lay Monitoring Program**. Preserve specimens in alcohol if possible, note the location where they were found, and send them in to confirm the identification.

To receive more information, request an educational presentation for your next group meeting, become involved in monitoring efforts, or confirm an identification, contact:

**Jeff Schloss**
**Lakes Lay Monitoring Program**
**55 College Road 109 Pettee Hall**
**University of New Hampshire**
**Durham NH 03824-3512**
**(603) 862-3848**

# Understanding Lake Aging (Eutrophication)

A common concern among **New Hampshire Lakes Lay Monitoring Program (NH LLMP)** participants is a perceived increase in the density and abundance of aquatic plants in the shallows, increases in the amount of microscopic plant "algal" growth (detected as greener water), and water transparency decreases, what is known as eutrophication. Eutrophication is a natural process by which all lakes age and progress from pristine, oligotrophic, lakes to nutrient enriched, eutrophic, lakes on a geological time frame; thousands of years. Much like the fertilizers applied to our lawns, nutrients which enter our lakes stimulate plant growth and culminate in greener (and in turn less clear) waters. Some lakes age at a faster rate than others due to natural attributes; watershed area, slope, soil type, mean lake depth, etc. Since our New Hampshire lakes were created during the last ice-age which ended about 10,000 years ago, we should have a natural continuum of lake states in New Hampshire ranging from pristine to enriched.

Classification criteria are often used to categorize lakes into what are known as **trophic states**, in other words, levels of lake productivity "greenness" (refer to Table 3 for a summary of commonly used eutrophication parameters). Oligotrophic lakes are considered "unproductive" pristine systems and are characterized by high water clarities, low nutrient concentrations, low algae concentrations, minimal levels of aquatic plant "weed" growth, and high dissolved oxygen concentrations near the lakebottom. Eutrophic lakes are considered "highly productive" enriched systems characterized by low water transparencies, high nutrient concentrations, high algae concentrations, large stands aquatic plants and very low dissolved oxygen concentrations near the lakebottom. Mesotrophic lakes have qualities between those of oligotrophic and eutrophic lakes and are characterized by moderate water transparencies, moderate nutrient concentrations, moderate algae growth, moderate aquatic plant "weed" growth and decreasing dissolved oxygen concentrations near the lakebottom.

**Table 3: Eutrophication Parameters and Categorization**

| Parameter | Oligotrophic "pristine" | Mesotrophic "transitional" | Eutrophic "enriched" |
|---|---|---|---|
| **Chlorophyll a (*ug*/l) *** | <3.0 | 3.0-7.0 | >7.0 |
| **Water Transparency (meters) *** | >4.0 | 2.5-4.0 | <2.5 |
| **Total Phosphorus (*ug*/l) *** | <15.0 | 15.0-25.0 | >25.0 |
| **Dissolved Oxygen (mg/l) #** | high | moderate | low |
| **Macroscopic Plant Abundance** | low | moderate | high |

*** Denotes classification criteria employed by Forsberg and Ryding (1980).**
**# Denotes dissolved oxygen concentrations near the lakebottom.**

Is a pristine, oligotrophic, lake "better than" an enriched, eutrophic, lake? Not necessarily. As indicated above, lakes will naturally exhibit varying degrees of productivity. Some lakes will naturally be more susceptible to eutrophication than others due

to natural attributes and in turn have aged more rapidly. However, human related activities can augment the aging process (what is known as cultural eutrophication) and result in a transition from a pristine system to an enriched system in tens of years rather than the natural transitional period which should take thousands of years. Cultural eutrophication is particularly a concern for northern New England lakes where large tracts of forested lands are being developed, culminating in an increased susceptibility of these lakes to sediment and nutrient loadings which tend to augment the eutrophication process. Additionally, other pollutants such as heavy metals, herbicides, insecticides and petroleum products might also affect your lake's "health". Human development can negatively affect water quality in a number of ways:

- Removal of shoreside vegetation - shoreside vegetation, what is known as riparian vegetation, provides a protective buffer that "traps" pollutants before reaching the lake. These buffers remove materials both chemically (through biological uptake) and physically (settling materials out). As riparian buffers are removed, materials are more likely to enter the lake and in turn favor declining water quality.
- Excessive fertilizer applications - fertilizers entering the lake can stimulate aquatic plant and algal growth and in extreme cases result in noxious algal blooms. Increases in algal growth tend to diminish water transparency and under extreme cases culminate in surface "scums" that can wash up on the shoreline and can also produce unpleasant smells as the material decomposes. Excessive nutrient concentrations also favor algal forms known to produce toxins which irritate the skin and under extreme conditions, are fatal when ingested.
- Increased organic matter loading - organic matter (leaves, grass clippings, etc.) are a major source of nutrients in the aquatic environment. As the vegetative matter decomposes nutrients are "freed up" and can become available for aquatic plant and algal growth. In general, we are not concerned with this material entering the lake naturally (leaf senescence in the fall) but rather excessive loading of this material as occurs when residents dump or rake leaf litter and grass clippings into the lake. This material not only provides large nutrient reserves which can stimulate aquatic plant and algal growth but also makes great habitat for leaches and other potentially undesirable organisms in swimming areas.
- Septic problems - faulty septic systems are a big concern as they can be a primary source of water pollution around our lakes. Septic systems are loaded with nutrients and can also be a health threat when not functioning properly.
- Creation of impervious surfaces - impervious surfaces reduce the water's capacity to infiltrate the soil and in turn go through nature's water purification system. As water seeps into the soil, pollutants are removed from the runoff through absorption onto soil particles. Biological processes detoxify substances and/or immobilize substances. Surface water runoff over impervious surfaces also increases water velocities which favor the transport of suspended and dissolved pollutants into your lake.

**How can you minimize water quality degradation?**

- First, you should refer to **Appendix B** for a review of the New Hampshire Department of Environmental Services Comprehensive Shoreland Protection Act (CSPA). The CSPA sets legal regulations aimed at protecting water quality and applies to several of the recommendations listed below. As the

CSPA is subject to revisions, you should call the New Hampshire Department of Environmental Services to find out whether or not the act has been changed. If you have any questions regarding the act or need further information contact the *Shoreline Protection Act Coordinator, Natilie Landry*, at (603) 271-2658.

- Maintain shoreside (riparian) vegetative cover when new construction is undertaken. For those who have preexisting houses but lack vegetative buffers, consider shoreline plantings aimed at diminishing the pollution load into your lake. Pertinent Resource:

  *Planting Shoreland Areas* (no charge) University of New Hampshire Publication Center. (603) 862-2346
- Minimize fertilizer applications whenever possible. Most people apply far more fertilizers than necessary, with the excess draining into your lake. This not only applies to those immediately adjacent to the lake but to everybody in the watershed. Pollutants in all areas of the watershed will ultimately make their way into your lake.
- Don't dump leaf litter or leaves into the lake. Compost the material or take it to a proper waste disposal center.
- Septic systems will not function efficiently without the proper precautionary maintenance. Have your septic system inspected every two to four years and pumped out when necessary. Since the septic system is such an expensive investment often costing around $10,000 for a complete overhaul, it is advantageous to assure proper care is taken to prolong the system's life. Additionally, following proper maintenance practices will reduce water quality degradation. Pertinent Resources:

  *Septic Systems, How they work and how to keep them working.* $1.00/ea University of New Hampshire Publications Center (603) 862-2346
  *Pipeline: Fall 1995 Vol. 6, No. 4. Maintaining Your Septic System-A Guide for Homeowners.* (cost of shipping & handling; 10 or less). 1-800-624-8301

**Refer to the following publications for an overview of some do's and don'ts associated with water quality preservation and for listings of additional resources:**

*Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities.* Audobon Society of New Hampshire. 3 Silk Farm Road, Concord NH 03301 (603) 224-9909

*Best Management Practices to Control Nonpoint Source Pollution: A Guide for Citizens and Town Officials.* May 1994. NHDES-WSPCD-94-2. New Hampshire Department of Environmental Services. 6 Hazen Drive, Concord NH 03301 (603) 271-3503

*A Guide to Developing and Re-Developing Shoreland Property in New Hampshire: A Blueprint to Help You Live by the Water.* North Country Resource Conservation and Development Area, Inc. 103 Main Street-Suite #1,. Meredith NH 03253-9266 (603) 279-6546

# Rainfall... People... and Lake Water Quality

By: Alan L .Baker
Professor of Aquatic Ecology
University of New Hampshire

High quality lakes will always remain an invaluable attraction to people, thus an important element of New Hampshire's economy. Questions about changes in water quality and clarity are often asked. Now data which have been gathered by University of New Hampshire researchers, in cooperation with many volunteer monitors, are beginning to provide some answers to questions such as: *Have our lakes degraded in this century? Is water quality currently deteriorating? What is causing changes to occur?* Now we can begin to answer these questions.

## Dynamic Lakes

In order to understand the answers, one must have some awareness of Limnology - the study of the geologic, physical, chemical and biological dynamics of lakes. It is important to be alert to the changing nature of lakes, their sensitivity to disturbances, and their likelihood to degrade or improve in quality in response to poor or good protection strategies.

It is possible to identify many characteristics that determine the uniqueness of each lake and help to distinguish a blue jewel from a septic waste depot. Volunteer monitors from the **N.H. Lakes Lay Monitoring Program (LLMP)** have amassed data from more than 100 New Hampshire lake sites over the past decade. The objective of this effort, established in 1978, was to develop information to scientifically document long-term trends in water quality.

It is now possible to understand the kinds of disturbances that modify the characteristics of a lake for better or worse. This cooperative effort between lakeshore property owners and UNH researchers has established how lake water quality changes over the decades. Based upon accumulated data it is possible to use a model to predict these events.

## The Overview

Although each New Hampshire lake is unique, and there is a diversity of lake types in the state, the **LLMP** data reveal a remarkably common pattern in the "behavior" of most lakes. Researches anticipated that multiple sites within any given lake would have the same characteristics. There is also strong evidence that large and small lakes follow a similar pattern of changes, within the ice-free period of a single year as well as through nearly two decades of observations. This is quite a surprise! *How can unique lakes in unique watershed "behave" in such a similar manner?*

The "long-term" changes in water quality characteristics are not always monotonously negative, but appear to fluctuate corresponding to 11-year cycles of solar

flares or sunspots. What is the role of human behavior? There is no cyclic pattern to human activity on lakes.

*Why, for example, did Squam Lake become greener from 1979 through 1984, then suddenly clarify in 1985? Why did the clarity of nearly all lakes in the* ***LLMP*** *program improve in 1985? Why did the chlorophyll (the major pigment in microscopic plants) decrease significantly in the same year? Furthermore, why was total phosphorous in the water very low in 1985? Why was there a relatively high Acid Neutralizing Capacity in that year? (ANC is the capacity of a lake to absorb or buffer higher levels of acidity in the water). Finally, why have all these water quality parameters changed together in the reverse direction from 1986 to 1993?*

A few lakes have "misbehaved" and followed opposite trends during the same period, but this can be attributed to their unique characteristics, and to site-specific circumstances.

## The Hunch

New Hampshire is a relatively small state. Despite other diversities, our lakes are all subjected to the climate we enjoy at 43° to 44° North latitude. The whimsical nature of New England weather, difficult to predict, variable from season to season and year to year, is well known. *Could it be that our lakes are responding to climatic variation and global warming? What was unique about 1985?*

A reasonable hunch was that changes in total rainfall could be the "pied piper" playing the tune to which the lakes have danced. A comparison of rainfall data from 30 National Oceanographic and Atmospheric Administration weather stations confirmed that the state is basically a single climate region. While rainfall is much higher in some areas than others, the pattern is similar no matter where one looks. A dry year is a dry year and a wet year is a wet year, statewide. The record rainfall between July 1984 and June 1985 occurred during a period of sub-normal rainfall relative to 30-year averages.

So! We have a clue.

## The Model

The majority of New Hampshire's lakes are what is known as "nutrient limited." This means that certain nutrients, especially phosphorus and nitrogen, when present in lake water stimulate high levels of growth in microscopic aquatic plants such as algae and phytoplankton. Humans, along with other creatures, process these nutrients quickly and deposit them in lakes or in water flowing down a watershed.

In addition, most watersheds in New Hampshire are small and have steep topography. The streams within these watersheds are typically short and fast-flowing, delivering rainwater to lakes very quickly. Thus, episodes of high rainfall deliver more nutrients by washing them into lakes from watersheds. Prolonged periods (up to one year) of high rainfall lead to more nutrient loading and higher total phosphorus levels, therefore greener and less transparent lakes. In addition, sulfur dioxide in rainwater--the ingredient that causes acid rain -- and solutes (dissolved acids) collected within the watershed, lowers the ANC of our lakes, i.e., the capacity of lakes to buffer the effects of acidity is diminished.

At its present state of development, the LLMP model suggests that the total volume of rainfall is the cause of both seasonal and long-term annual changes in lake water quality throughout New Hampshire. Most lakes "improved" in dry years such as 1985 and "degrade" in wetter years such as 1984 and 1986. The model works to the extent that the loading of nutrients into nutrient-deprived lakes is dependent on rainfall, and this appears to be the case.

Further verification of the model comes from the few more productive lakes, i.e., those higher in naturally occurring levels of nutrients. The "richer" in nutrients a lake, the "greener" it tends to be. Such "rich" lakes tend to be "diluted" by the loading of stormwater running off the watershed. This again directly implicates rainwater as the "piedpiper" which causes such lakes to be somewhat less productive, therefore "improved," during wet years.

## Implications

At least two important predications can be developed when interpreting the LLMP model. First, changes in rainfall volume associated with global warming will influence lake water quality directly. If New Hampshire becomes drier, the lakes will tend to remain transparent and on that basis, will likely "improve" in water quality. Otherwise, a wetter future will likely deplete water quality to some extent.

Second, the model provides substantial evidence that our lakes are sensitive to changes in nutrient loading. Such loading can be controlled to a large extent by the choices people make with regard to activities within a watershed area. Such activities include land use and development patterns and practices within the watershed area, as well as along the shoreland areas of lakes and streams. Human activity on the water can also have some impact on nutrient loading of lakes (see Spring 1995 *Lakeside*).

Efforts to minimize nutrient loading can make a difference. Such practices as:

- routine pumping of septic systems
- erosion control
- maintaining buffer and wooded areas near lakes and within watershed
- control of storm water run-off from roof tops, impermeable driveways and parking lots

all help to minimize nutrient transport to lakes.

## Future Concerns

While we can predict lake water quality parameters based upon weather patterns in a given year or over a period of years, there are a number of issues that require more comprehensive and thoughtful policy development if New Hampshire's lakes are going to remain the blue gems that we take for granted.

here are some of the unresolved issues:

- The survival of each lake given the multiple uses which they receive now, and will receive in the next millennium.
- The study of lake capacity, or use beyond which a lake becomes undesirable.

- The possibility that lakes will lose their aesthetic and economic value if they visibly degrade over time.
- The establishment of a comprehensive statewide lake use plan to manage our lakes effectively.

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# The Zebra Mussel Threat to New Hampshire

By: Jeff Schloss
UNH Cooperative Extension
Water Resource Specialist

The Zebra Mussel, a non-native freshwater mollusk that has successfully invaded a host of lakes and rivers throughout northeastern and central North America, continues its expansion towards New Hampshire. In the past three years, primarily due to the efforts of state agencies like **New Hampshire Fish Game** and **New Hampshire Department of Environmental Services (DES)**, the New Hampshire Lakes Association as well as local lake associations, residents and visitors have started to become aware of this non-native aquatic nuisance. All of these groups have been assisted by the University of New Hampshire (UNH) SeaGrant and Water Resource Extension Programs of the Northern New England Mussel Watch.

These tenacious little shellfish have caused almost a billion dollars worth of trouble in the Great Lakes region of the US and Canada. More recently, they impacted water suppliers and a federal fish hatchery on Lake Champlain in neighboring Vermont to the tune of millions of dollars. Thus, there is great concern with this potential threat to New Hampshire's precious fresh waters. But given the fact that many lakes and streams have very soft waters (they contain low mineral content especially that of calcium which is important for reproduction and shell construction) how concerned should we be?

## TABLE 4:

## ZEBRA MUSSEL COLONIZATION POTENTIAL

Based on environmental tolerances of known wild and lab populations in Europe and North America

(modified from C. O'Neill, NY SeaGrant Zebra Mussel Clearing House 6/95)

| Variable | High Potential | Moderate Potential | Low Potential | Very Low Potential | NH Summer Range * | NH Summer Average * |
|---|---|---|---|---|---|---|
| SALINITY (ppt) | 0 - 1 | 1 - 4 | 4 - 10 | 10 - 35 | none | less than 0 |
| CALCIUM (mg/L) | > 25 | 20 -25 | 9 - 20 | < 9 | <1 - 32 | 3.4 |
| pH (units) | 7.4 - 8.5 | 7.0 - 7.4<br>8.5 - 9.0 | 6.5 -7.0 | < 6.5<br>> 9.0 | 4.4 - 9.6 | 6.0 |
| WATER TEMP.°C) | 18 - 25 | 16 -18<br>25 -29 | 9 -15<br>28 - 30 | < 8<br>> 30 | 9.8 - 30 | varies by depth |
| DISSOLVED OXYGEN (ppm) | 8 - 10 | 6 - 8 | 4 - 6 | < 4 | 0 - 12 | generally > 6 in upper layer |
| CONDUCTIVITY (umhos at 25°C) | > 83 | 37 - 82 | 22 - 36 | < 21 | 13 - 350 | 55 |
| CHLOROPHYLL | Greater than | 2 ppb | CHL a | (algae level) | 0.1 - 144 | 7.2 |

* Summer upper water (epilimnetic) layer data from UNH Freshwater Biology Group and NH DES Limnology Center
data bases 1978 to 1993; total of 597 NH lakes sampled.
> = greater than; < = less than.

Table 4 breaks down the colonization potential of Zebra Mussels according to the water conditions they encounter. As can be seen, most of our fresh waters meet their temperature, algae, salinity and oxygen requirements. Limiting colonization for a majority of our lakes is pH and calcium content. It is ironic that the conditions that hurt us most in combating acid rain impacts may be our saving grace in preventing dense colonies of mussels. Of the two parameters, calcium is the more critical in that the pH of even the softest waters can increase to more tolerable levels due to the photosynthetic activity of submerged plants and algae (the removal of carbon dioxide from the water raises the pH in dense weed beds and in more productive lakes).

Care must be taken in concluding how safe we really are from infestation. These data are only from known zebra mussel habitats. In the lab, zebra mussels have successfully reproduced at salinities as high as 15 parts per thousand. Also, the lower limit of the calcium requirement continues to fall with time.

So which of our waters are most susceptible to Zebra Mussel colonization? Table 5 lists those waters with calcium concentrations of 9 parts per million or greater. There are two lakes that have water conditions highly conducive to colonization, three lakes with moderate potential and at least 16 lakes with low potential (an additional 8 lakes have calcium levels just under 9 parts per million). Most are located somewhere near the Connecticut River that has limestone deposits that can contribute calcium to nearby waters. The others are in the lower Merrimack River valley. There are also some close to the sea coast. UNH Sea Grant has initiated monitoring for adult mussels on the majority of these lakes through existing **NH LLMP (UNH), VLAP (DES)** and Cooperative Extension/SeaGrant monitoring programs.

**Table 5. Lakes Most Susceptible to Zebra Mussel Colonization.**

| Lake | | Town |
|---|---|---|
| Horseshoe | (low risk) | Merrimack |
| Harris Pond | | Pelham |
| Kimball Pond | | Canterbury |
| Post Pond | | Lyme |
| Sebbins Pond | (med. risk) | Bedford |
| Wilder Lake | | Lebanon |
| Cobbetts Pond | | Windham |
| Crystal Lake | | Manchester |
| Ogontz Lake | | Lyman |
| Moses Pond | | Plainfield |
| Dorrs Pond | | Manchester |
| World End Pond | | Salem |
| Otternick Pond | | Hudson |
| Fish Pond | | Columbia |
| Flints Pond | | Hollis |
| Taylor River | | Hampton |
| Kendall Pond | | Londonderry |
| Stevens Pond | | Manchester |
| Lime Pond | (high risk) | Columbia |
| Mill Pond | | Portsmouth |

While our current understanding of the mussels may allow for a brief sigh of relief on the part of our low calcium lakes, boaters and anglers should still continue to take the proper precautions on all waters. We are still continuing to amass all of the available information and research on these persistent little shellfish. The most frightening information indicates that these critters are becoming more at home in a wider range of water conditions; the water conditions within the mussels American range are much wider than those found in the mussels native habitat in Central Europe. Zebra Mussels have only been in our country since sometime around 1988 while they have been known to occur in large freshwater lakes such as the Black, Caspian and Aral seas for hundreds

if not thousands of years. This means that the invading mussels have been adapting quickly. Remember also that our native shellfish have adapted very well to our soft waters.

That is the reason zebra mussel warning signs have been posted with information posters and pamphlets at public areas and boat-launch sites. These materials are in place at lakes with higher calcium levels as well as high boat traffic areas. In addition, these precautions will minimize the risk of introducing non-native weeds like milfoil and other new plant and animal invaders that could eventually find a way into New Hampshire.

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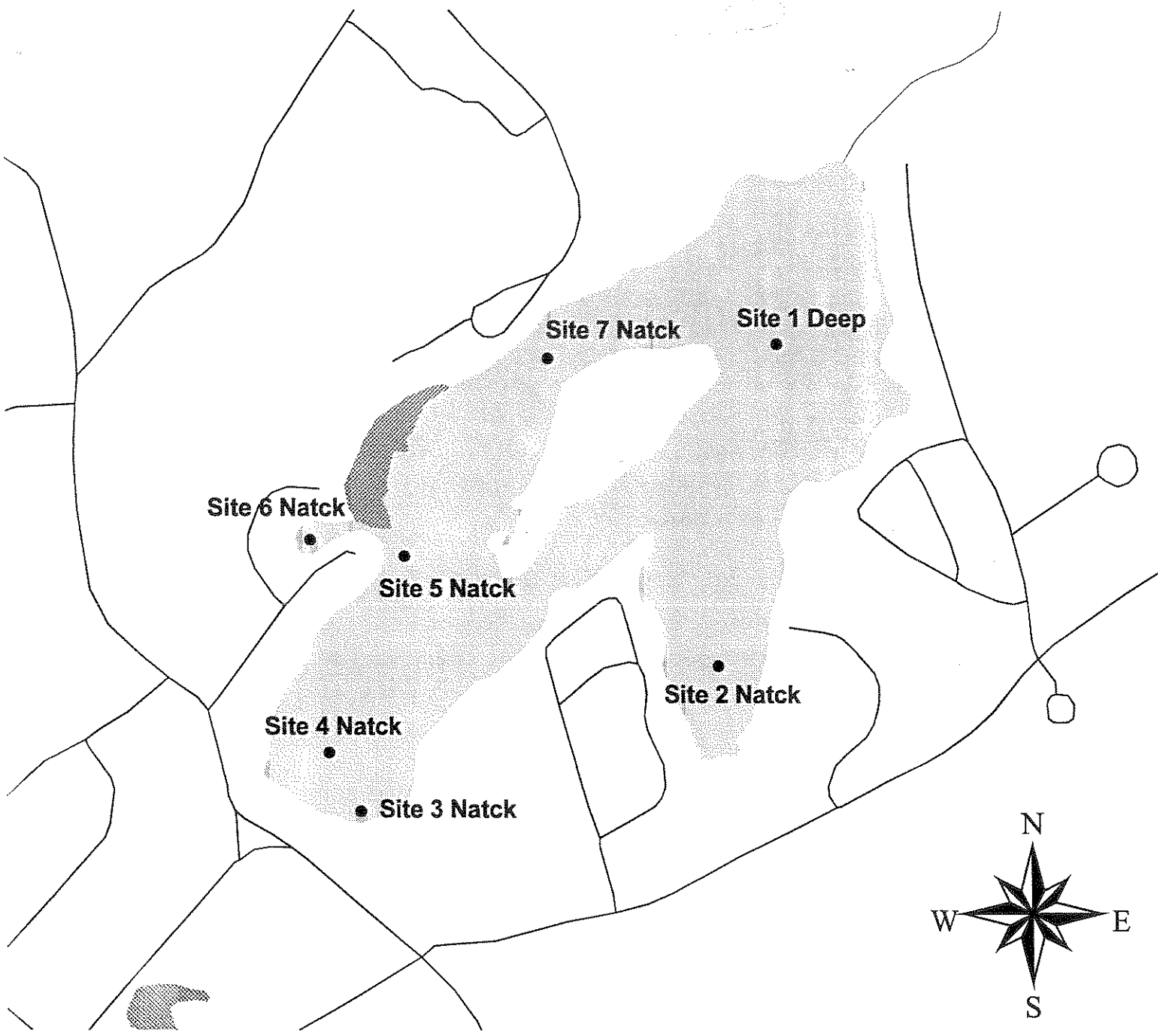
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# REPORT FIGURES

**Figure 11.** Location of the 1996 Naticook Lake deep and near shore sampling stations.

# Naticook Lake




Stream

Roads

Wetland

Sampling Sites

Naticook Lake

0.2 0 0.2 0.4 Miles

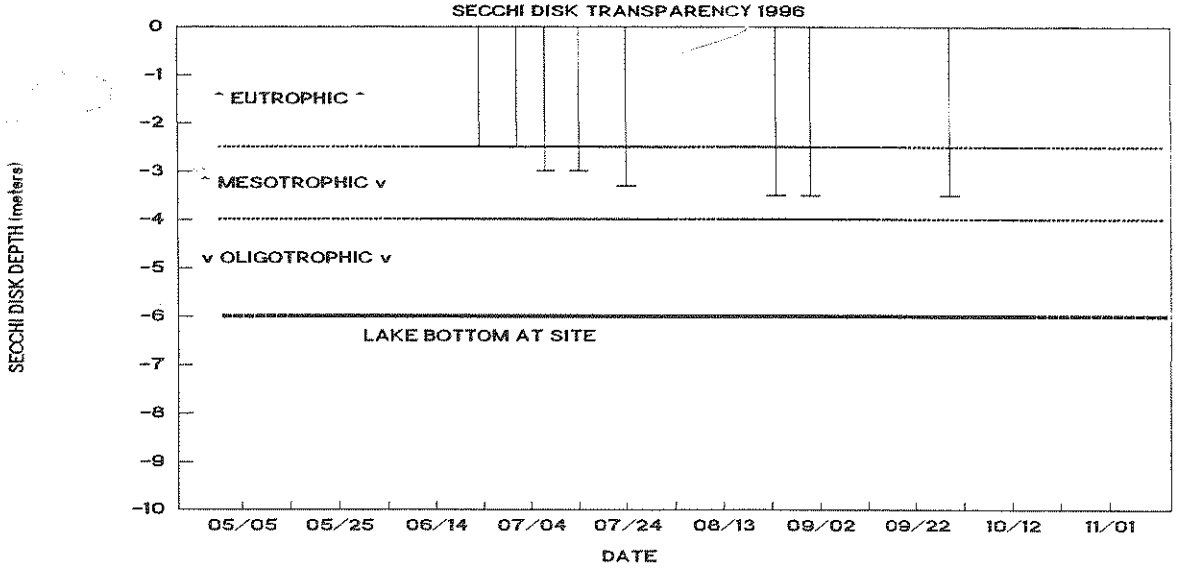
**Figure 12.** Naticook Lake, 1996. Seasonal Secchi Disk (water transparency) trends for Site 1 Deep. The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes. Secchi Disk transparency is reported to the nearest tenth (0.1) of a meter.

**Figure 13.** Naticook Lake, 1996. Seasonal chlorophyll *a* trends for Site 1 Deep. Chlorophyll *a* concentrations are expressed as parts per billion (ppb). The dotted horizontal lines on the plot border the ranges common to oligotrophic, mesotrophic and eutrophic lakes.

**Figure 14.** Naticook Lake, 1996. Seasonal dissolved color trends for lay monitor Site 1 Deep. Dissolved color is expressed as platinum cobalt units (ptu). The dotted horizontal line represents the 1996 dissolved color average for participating **LLMP** lakes.

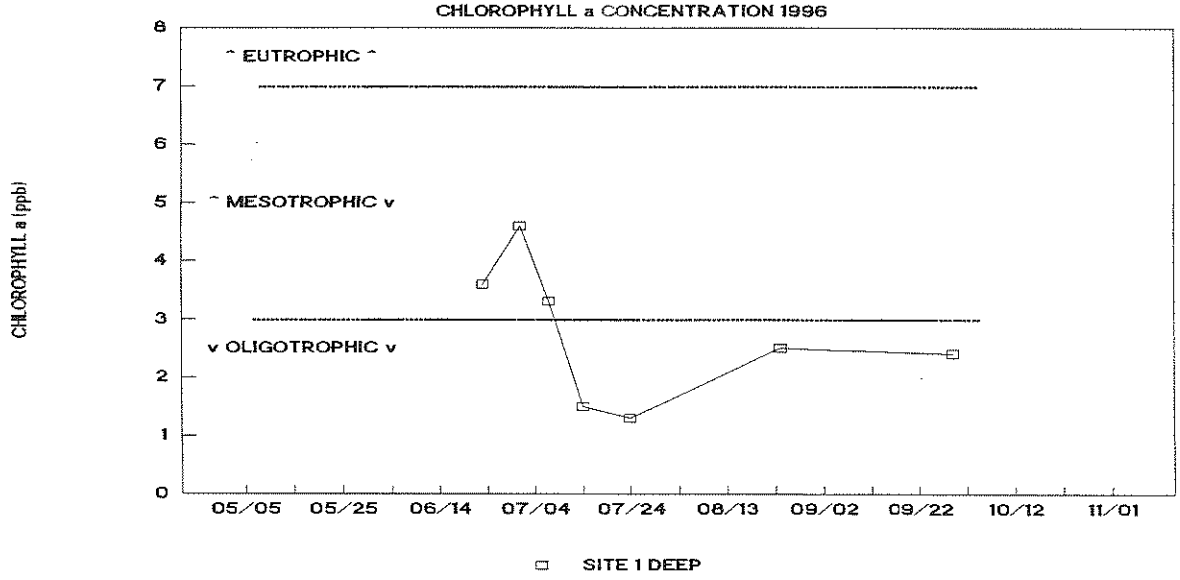
# NATICOOK LAKE – SITE 1 DEEP

SECCHI DISK TRANSPARENCY 1996




# NATICOOK LAKE

CHLOROPHYLL a CONCENTRATION 1996




# NATICOOK LAKE

DISSOLVED COLOR CONCENTRATION 1996

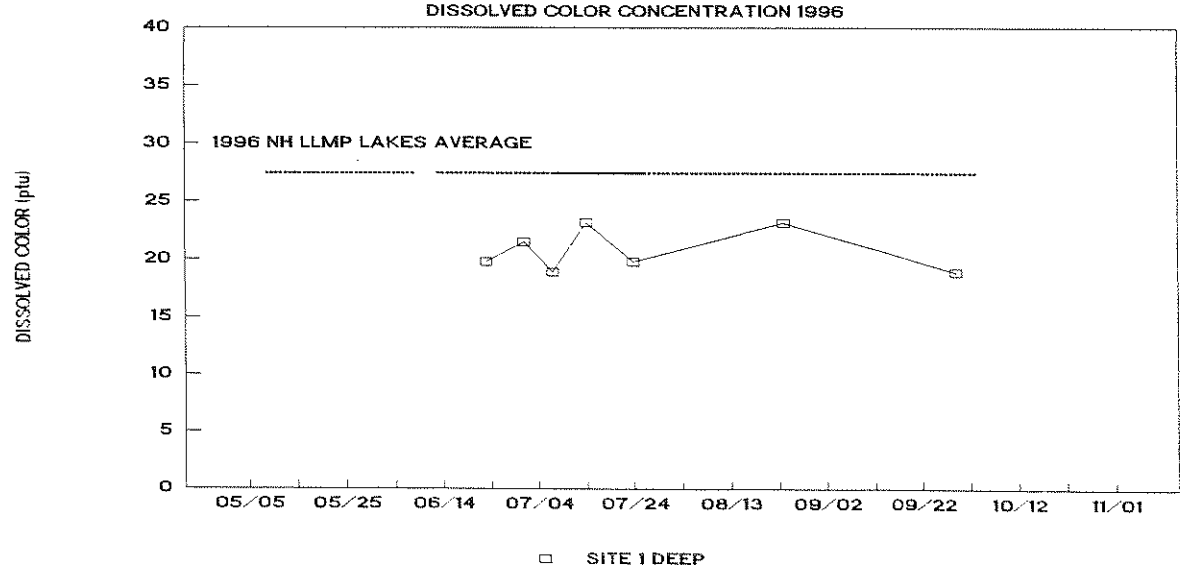
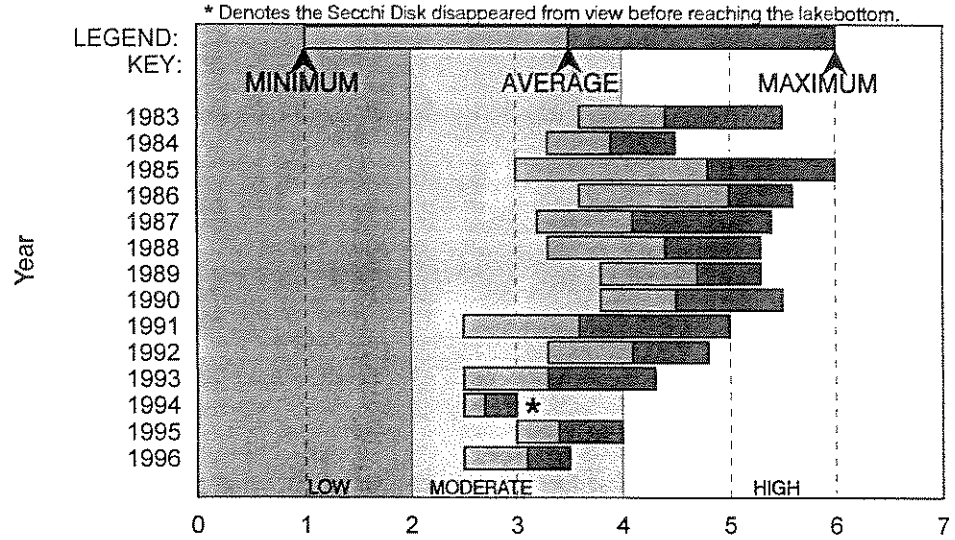


**Figure 15.** Comparison of the 1996 Naticook Lake, Site 1 Deep, lay monitor Secchi Disk transparency data with previous yearly data. The shaded regions on the graph denote the ranges characteristic of low, moderate and high Secchi Disk transparencies. The higher the Secchi Disk transparency the clearer the water. Secchi Disk readings are measured to the nearest tenth (0.1) of a meter.

**Figure 16.** Comparison of the 1996 Naticook Lake, Site 1 Deep, lay monitor chlorophyll *a* data with previous yearly data. The shaded regions on the graph denote chlorophyll *a* concentrations typical of unproductive, moderately productive and highly productive lakes. The higher the chlorophyll *a* concentration the greener the water (i.e. more algal growth).

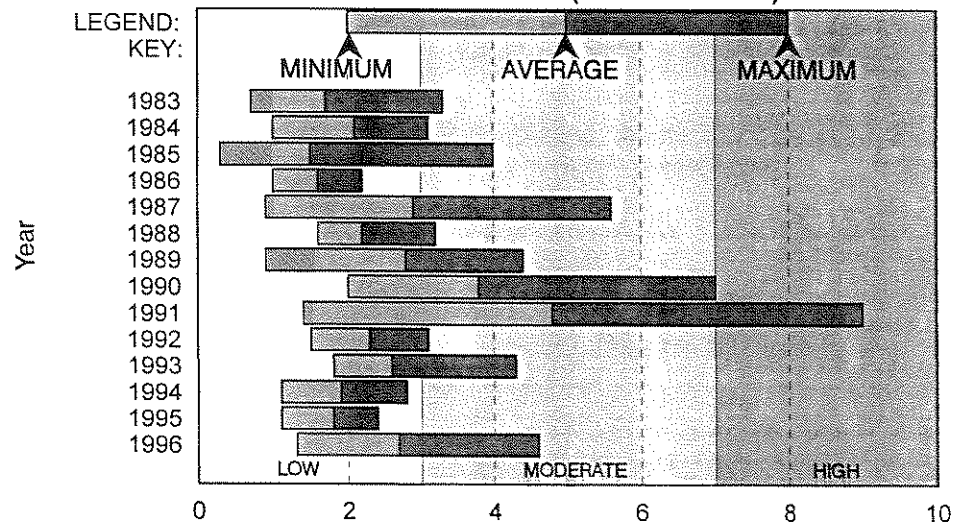
# NATICOOK LAKE - SITE 1 DEEP
## LAY MONITOR SECCHI DISK DATA
### YEARLY COMPARISONS (1983-1996)




The higher value = clearer water

Secchi Disk Depth (meters)

# NATICOOK LAKE - SITE 1 DEEP
## LAY MONITOR CHLOROPHYLL *a* DATA
### YEARLY COMPARISONS (1983 -1996)



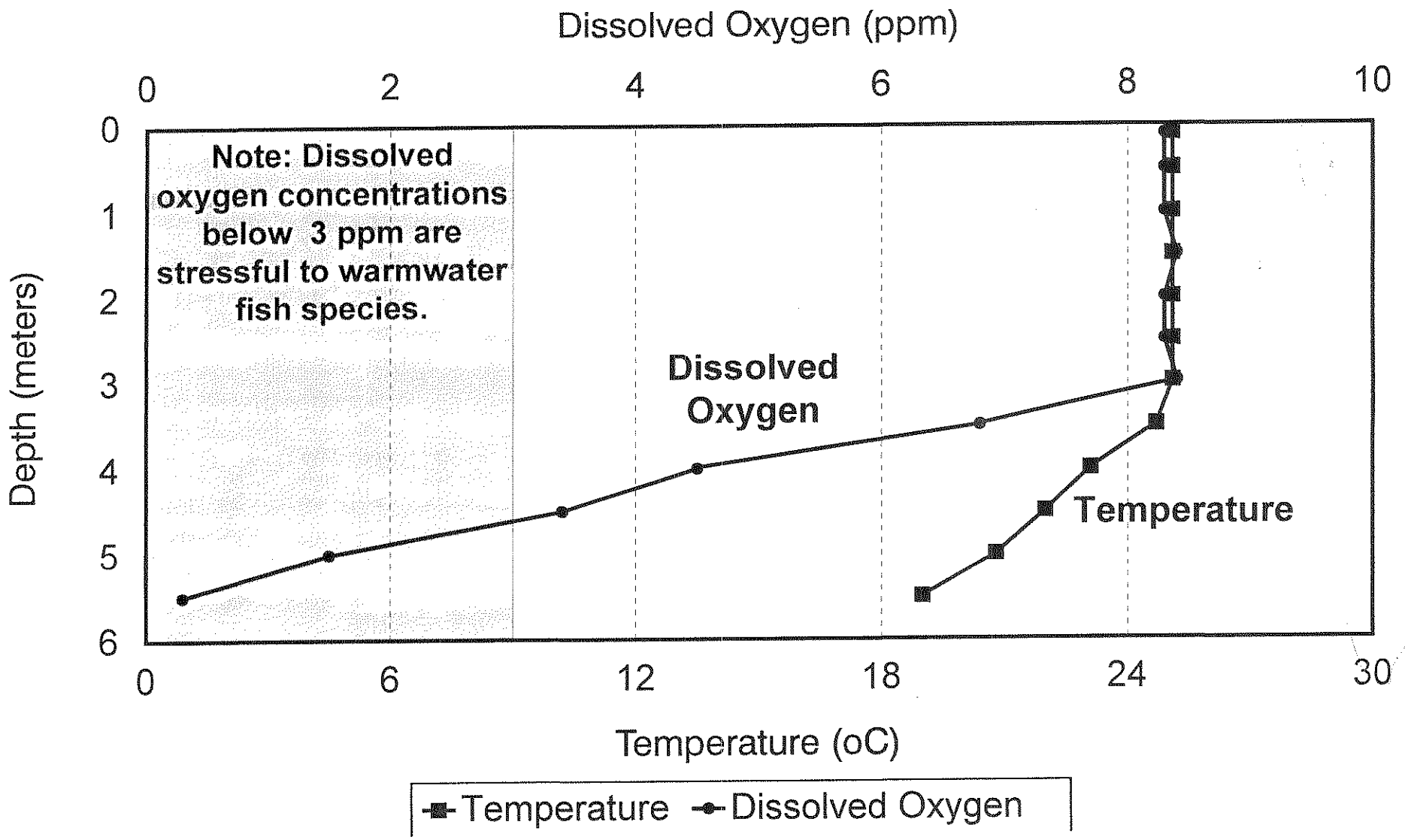

The higher value = more algal growth

Chlorophyll a (ppb)

**Figure 17.** Temperature and dissolved oxygen profiles collected at the Naticook Lake deep sampling station, Site 1 Deep, on August 13, 1996. The gray shaded region on the graph denotes dissolved oxygen concentrations stressful to warmwater fish. The temperature and dissolved data were collected at one-half meter increments and are reported as degrees Centigrade and as parts per million (ppm), respectively. *Notice the lower dissolved oxygen concentrations in the deeper waters.*

# Naticook Lake - Site 1 Deep

## Dissolved Oxygen and Temperature Profiles (August 13, 1996)



# APPENDIX A

**Lakes Lay Monitoring Program, U.N.H.**
**[Lay Monitor Data]**

Naticook Lake, NH
-- subset of trophic indicators, all sites, 1996

1996 SUMMARY

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Average transparency: | 3.1 | (1996: | 8 | values; | 2.5 | - | 3.5 | range) |
| Average chlorophyll: | 2.7 | (1996: | 7 | values; | 1.3 | - | 4.6 | range) |
| Average phosphorus: | 17.2 | (1996: | 18 | values; | 5.5 | - | 114.7 | range) |
| Average alk (gray): | 14.3 | (1996: | 7 | values; | 13.4 | - | 15.1 | range) |
| Average alk (pink): | 15.6 | (1996: | 7 | values; | 14.9 | - | 16.2 | range) |
| Average color, 440: | 20.7 | (1996: | 7 | values; | 18.9 | - | 23.2 | range) |

| Site | Date | Trans-parency (m) | Chl *a* (ppb) | Total Phos (ppb) | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Color Pt-Co units |
|---|---|---|---|---|---|---|---|
| 1 Deep | 06/23/1996 | 2.5 | 3.6 | 8.8 | 13.6 | 15.6 | 19.8 |
| 1 Deep | 07/01/1996 | 2.5 | 4.6 | 10.8 | 14.8 | 15.7 | 21.5 |
| 1 Deep | 07/07/1996 | 3.0 | 3.3 | 8.3 | 15.1 | 16.2 | 18.9 |
| 1 Deep | 07/14/1996 | 3.0 | 1.5 | 5.5 | 13.9 | 15.3 | 23.2 |
| 1 Deep | 07/24/1996 | 3.3 | 1.3 | 7.0 | 14.7 | 15.6 | 19.8 |
| 1 Deep | 08/24/1996 | 3.5 | 2.5 | 8.0 | 14.5 | 15.8 | 23.2 |
| 1 Deep | 08/31/1996 | 3.5 | ---- | 10.0 | ---- | ---- | ---- |
| 1 Deep | 09/29/1996 | 3.5 | 2.4 | 9.5 | 13.4 | 14.9 | 18.9 |
| 2 Natck | 07/14/1996 | ---- | ---- | 12.0 | ---- | ---- | ---- |
| 2 Natck | 09/29/1996 | ---- | ---- | 7.8 | ---- | ---- | ---- |
| 3 Natck | 07/14/1996 | ---- | ---- | 46.6 | ---- | ---- | ---- |
| 3 Natck | 09/29/1996 | ---- | ---- | 114.7 | ---- | ---- | ---- |
| 4 Natck | 07/14/1996 | ---- | ---- | 11.5 | ---- | ---- | ---- |
| 4 Natck | 09/29/1996 | ---- | ---- | 9.3 | ---- | ---- | ---- |
| 5 Natck | 07/14/1996 | ---- | ---- | 12.0 | ---- | ---- | ---- |
| 5 Natck | 09/29/1996 | ---- | ---- | 12.5 | ---- | ---- | ---- |
| 6 Natck | 07/14/1996 | ---- | ---- | 10.3 | ---- | ---- | ---- |
| 6 Natck | 09/29/1996 | ---- | ---- | 5.8 | ---- | ---- | ---- |

<< End of 1996 listing, 18 records >>

**Lakes Lay Monitoring Program, U.N.H.**
**[FBG Data August 13, 1996]**

| Site | Depth (m) | Chl *a* (ppb) | pH | Free CO2 (ppm) | Alk Gray end pt. | Alk Pink end pt. | Spec. Cond. (umho) | Total Phos. (ppb) |
|---|---|---|---|---|---|---|---|---|
| 1 Deep | 0-3.0 | 2.4 | ---- | ---- | 16.4 | 17.0 | ---- | 11.3 |
| 1 Deep | 0.5 | ---- | 7.0 | 1.6 | 17.3 | 17.8 | ---- | ---- |
| 1 Deep | 2.0 | ---- | 7.0 | 1.6 | 16.6 | 17.4 | ---- | ---- |
| 1 Deep | 4.0 | 5.1 | 6.7 | 2.6 | 18.6 | 19.2 | ---- | 15.0 |
| 1 Deep | 5.0 | ---- | 6.5 | 6.2 | 20.2 | 21.3 | ---- | 17.3 |
| 2 Natck | 0.5 | ---- | ---- | ---- | ---- | ---- | 219.6 | 9.0 |
| 3 Natck | 0.5 | ---- | ---- | ---- | ---- | ---- | 224.5 | 9.3 |
| 4 Natck | 0.5 | ---- | ---- | ---- | ---- | ---- | 221.2 | 8.8 |
| 7 Natck | 0.5 | ---- | ---- | ---- | ---- | ---- | 220.8 | 9.8 |

| Site | Secchi Disk Transparency (meters) |
|---|---|
| 1 Deep | 5.0 meters |

| Depth (m) | Tem-pera-ture (°C) | Diss. oxygen (mg/l) | SPCD (uS) |
|---|---|---|---|
| 0.10 | 25.1 | 8.3 | 218.0 |
| 0.50 | 25.1 | 8.3 | 218.0 |
| 1.00 | 25.1 | 8.3 | 219.4 |
| 1.50 | 25.1 | 8.4 | 219.2 |
| 2.00 | 25.1 | 8.3 | 219.3 |
| 2.50 | 25.1 | 8.3 | 219.3 |
| 3.00 | 25.1 | 8.4 | 219.3 |
| 3.50 | 24.7 | 6.8 | 219.6 |
| 4.00 | 23.1 | 4.5 | 215.5 |
| 4.50 | 22.0 | 3.4 | 214.5 |
| 5.00 | 20.8 | 1.5 | 214.8 |
| 5.50 | 19.0 | 0.3 | 215.3 |

**Lakes Lay Monitoring Program, U.N.H.**
**[Historical Lay Monitor Data]**

| Site | Date | Trans-parency (m) | Chl a (ppb) | Color Pt-Co units | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Total Phos (ppb) |
|---|---|---|---|---|---|---|---|
| 1 Deep | JUN-24-1983 | 5.4 | 0.8 | ---- | ---- | ---- | ---- |
| 1 Deep | JUN-29-1983 | 5.5 | 0.7 | ---- | ---- | ---- | ---- |
| 1 Deep | JUL-06-1983 | 4.5 | 0.9 | ---- | ---- | ---- | ---- |
| 1 Deep | JUL-13-1983 | 3.6 | 3.3 | ---- | ---- | ---- | ---- |
| 1 Deep | JUL-20-1983 | 4.0 | 1.5 | ---- | ---- | ---- | ---- |
| 1 Deep | JUL-31-1983 | 3.6 | 2.5 | ---- | ---- | ---- | ---- |
| 1 Deep | AUG-03-1983 | 4.5 | 2.0 | ---- | ---- | ---- | ---- |
| 1 Deep | AUG-21-1983 | 4.4 | 1.6 | ---- | ---- | ---- | ---- |
| 1 Deep | AUG-28-1983 | 4.0 | 1.6 | ---- | ---- | ---- | ---- |
| 1 Deep | JUL-05-1984 | 3.6 | 3.1 | ---- | ---- | ---- | ---- |
| 1 Deep | JUL-11-1984 | 4.3 | 3.0 | ---- | ---- | ---- | ---- |
| 1 Deep | JUL-19-1984 | 3.3 | 1.9 | ---- | ---- | ---- | ---- |
| 1 Deep | JUL-25-1984 | 3.5 | 1.4 | ---- | ---- | ---- | ---- |
| 1 Deep | AUG-03-1984 | 3.9 | 2.1 | ---- | ---- | ---- | ---- |
| 1 Deep | AUG-08-1984 | 3.6 | 2.3 | ---- | ---- | ---- | ---- |
| 1 Deep | AUG-15-1984 | 3.7 | 2.7 | ---- | ---- | ---- | ---- |
| 1 Deep | AUG-24-1984 | 4.4 | 1.0 | ---- | ---- | ---- | ---- |
| 1 Deep | SEP-16-1984 | bottom | 1.2 | ---- | ---- | ---- | ---- |
| 1 Deep | JUN-02-1985 | 6.0 | 2.0 | 24.1 | ---- | ---- | ---- |
| 1 Deep | JUN-09-1985 | 6.0 | 1.0 | 28.3 | ---- | ---- | ---- |
| 1 Deep | JUN-14-1985 | ---- | ---- | ---- | ---- | ---- | 5.6 |
| 1 Deep | JUN-25-1985 | 4.6 | 2.1 | 23.2 | ---- | ---- | 7.6 |
| 1 Deep | JUL-02-1985 | 5.3 | 0.8 | 13.7 | ---- | ---- | ---- |
| 1 Deep | JUL-11-1985 | 4.3 | 0.9 | 13.7 | ---- | ---- | 4.1 |
| 1 Deep | JUL-24-1985 | 3.3 | 3.1 | 15.5 | ---- | ---- | 3.0 |
| 1 Deep | AUG-01-1985 | 3.0 | 4.0 | 12.9 | ---- | ---- | ---- |
| 1 Deep | AUG-01-1985 | ---- | ---- | ---- | ---- | ---- | 5.9 |
| 1 Deep | AUG-01-1985 | ---- | ---- | ---- | ---- | ---- | 1.8 |
| 1 Deep | AUG-09-1985 | ---- | ---- | ---- | ---- | ---- | 2.8 |
| 1 Deep | AUG-22-1985 | ---- | ---- | ---- | ---- | ---- | 7.1 |
| 1 Deep | SEP-01-1985 | 5.5 | 0.3 | 16.3 | 12.8 | 14.2 | 26.9 |
| 1 Deep | SEP-14-1985 | 5.3 | 0.8 | 15.5 | 11.5 | 12.6 | 6.9 |
| 1 Deep | SEP-22-1985 | 4.3 | 1.1 | 10.3 | 10.6 | 12.1 | ---- |
| 1 Deep | OCT-30-1985 | 5.6 | 0.4 | ---- | 9.9 | 10.9 | ---- |
| 1 Deep | JUN-24-1986 | 5.6 | 2.1 | 15.5 | ---- | ---- | ---- |
| 1 Deep | JUL-03-1986 | 5.5 | 1.6 | 16.3 | 11.7 | 12.1 | ---- |
| 1 Deep | JUL-15-1986 | 5.4 | 1.5 | 13.7 | 11.6 | 12.0 | 2.7 |
| 1 Deep | JUL-22-1986 | 5.4 | 1.0 | 12.9 | 12.3 | 12.9 | ---- |
| 1 Deep | JUL-31-1986 | 3.6 | 1.2 | 13.7 | 12.4 | 13.3 | ---- |
| 1 Deep | AUG-10-1986 | ---- | ---- | ---- | ---- | ---- | 3.4 |
| 1 Deep | AUG-14-1986 | 4.3 | 2.2 | 10.3 | 12.3 | 13.3 | ---- |
| 1 Deep | AUG-21-1986 | 4.0 | 1.8 | 18.0 | 12.6 | 13.0 | ---- |
| 1 Deep | AUG-23-1986 | ---- | ---- | ---- | ---- | ---- | 1.4 |
| 1 Deep | SEP-02-1986 | 5.0 | 2.0 | 8.6 | 12.2 | 13.5 | ---- |
| 1 Deep | SEP-07-1986 | 5.4 | 1.7 | 12.9 | 12.4 | 13.8 | 2.4 |
| 1 Deep | SEP-13-1986 | 5.5 | 1.0 | ---- | 12.4 | 13.2 | ---- |

| Site | Date | Trans-parency (m) | Chl *a* (ppb) | Color Pt-Co units | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Total Phos (ppb) |
|---|---|---|---|---|---|---|---|
| 1 Deep | SEP-27-1986 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 1 Deep | JUL-08-1987 | 4.4 | 1.8 | ---- | 11.5 | 12.3 | ---- |
| 1 Deep | JUL-17-1987 | 3.5 | 3.7 | ---- | 11.5 | 12.7 | ---- |
| 1 Deep | JUL-23-1987 | 3.8 | 4.8 | 15.5 | 12.1 | 12.9 | 12.3 |
| 1 Deep | AUG-05-1987 | 3.2 | 5.6 | 18.9 | 12.5 | 14.0 | ---- |
| 1 Deep | AUG-11-1987 | 3.3 | 3.2 | 18.9 | 12.7 | 13.4 | ---- |
| 1 Deep | AUG-18-1987 | 4.0 | 1.8 | 19.8 | 13.0 | 14.2 | 2.3 |
| 1 Deep | AUG-25-1987 | 3.8 | 4.5 | 24.9 | 11.9 | 12.9 | ---- |
| 1 Deep | SEP-01-1987 | 4.3 | 2.0 | 18.9 | 11.3 | 12.3 | 2.7 |
| 1 Deep | SEP-09-1987 | 4.8 | 1.1 | 18.0 | 11.5 | 12.4 | 2.7 |
| 1 Deep | SEP-21-1987 | 5.4 | 2.6 | 15.5 | 11.5 | 12.8 | ---- |
| 1 Deep | SEP-27-1987 | 5.0 | 0.9 | 12.0 | 10.7 | 11.8 | ---- |
| 1 Deep | JUL-03-1988 | 5.0 | 1.6 | ---- | 10.3 | 10.4 | 2.9 |
| 1 Deep | JUL-12-1988 | 5.0 | 2.0 | 16.3 | ---- | ---- | 4.6 |
| 1 Deep | JUL-23-1988 | 3.3 | 3.2 | 24.1 | 9.7 | 10.4 | 23.6 |
| 1 Deep | AUG-04-1988 | 3.8 | 2.0 | 20.6 | 12.1 | 14.5 | 9.9 |
| 1 Deep | AUG-11-1988 | 3.8 | 2.3 | 18.9 | 11.1 | 11.9 | 10.1 |
| 1 Deep | AUG-21-1988 | 3.3 | 2.7 | 18.0 | 10.2 | 11.1 | 7.9 |
| 1 Deep | AUG-26-1988 | 5.2 | 1.9 | 12.9 | 9.5 | 10.4 | ---- |
| 1 Deep | AUG-30-1988 | ---- | ---- | ---- | ---- | ---- | 7.3 |
| 1 Deep | SEP-02-1988 | 4.8 | 1.6 | 18.9 | 10.6 | 11.6 | ---- |
| 1 Deep | SEP-11-1988 | 4.8 | 2.6 | 12.9 | 10.8 | 11.4 | ---- |
| 1 Deep | OCT-02-1988 | 5.3 | 1.8 | 14.6 | 10.0 | 10.9 | ---- |
| 1 Deep | MAY-23-1989 | 5.3 | 0.9 | ---- | ---- | ---- | ---- |
| 1 Deep | JUN-14-1989 | 5.0 | 2.5 | 27.5 | 11.8 | 13.0 | 6.6 |
| 1 Deep | JUN-20-1989 | 4.8 | 2.9 | 29.2 | 12.2 | 13.5 | 5.9 |
| 1 Deep | JUN-29-1989 | 4.8 | 3.9 | 23.2 | ---- | ---- | ---- |
| 1 Deep | JUL-11-1989 | 4.1 | 2.5 | 22.3 | 13.0 | 14.8 | 12.8 |
| 1 Deep | JUL-18-1989 | 4.5 | 2.1 | 21.5 | 12.3 | 13.5 | ---- |
| 1 Deep | JUL-25-1989 | 4.8 | 2.6 | 26.6 | 12.6 | 13.5 | ---- |
| 1 Deep | AUG-04-1989 | 4.6 | 2.2 | 19.8 | 12.1 | 13.1 | 9.9 |
| 1 Deep | AUG-11-1989 | ---- | ---- | ---- | ---- | ---- | 10.1 |
| 1 Deep | AUG-19-1989 | 3.8 | 4.4 | 18.9 | 12.4 | 13.7 | ---- |
| 1 Deep | AUG-21-1989 | ---- | ---- | ---- | ---- | ---- | 7.9 |
| 1 Deep | AUG-30-1989 | 5.3 | 2.7 | 16.3 | 11.8 | 12.8 | 7.3 |
| 1 Deep | SEP-13-1989 | 4.5 | 3.6 | 11.2 | 11.7 | 12.7 | 7.9 |
| 1 Deep | MAY-28-1990 | 4.5 | 2.6 | ---- | ---- | ---- | ---- |
| 1 Deep | JUN-28-1990 | 4.0 | 2.1 | ---- | ---- | ---- | ---- |
| 1 Deep | JUL-11-1990 | 4.8 | 4.1 | ---- | ---- | ---- | ---- |
| 1 Deep | JUL-23-1990 | 3.8 | 6.3 | 19.8 | 15.1 | 16.2 | 1.8 |
| 1 Deep | AUG-01-1990 | 4.8 | 3.2 | 16.3 | ---- | ---- | ---- |
| 1 Deep | AUG-08-1990 | 4.0 | 7.0 | 18.0 | 14.1 | 15.1 | 4.4 |
| 1 Deep | AUG-23-1990 | 3.8 | 4.7 | 18.9 | 14.2 | 14.8 | ---- |
| 1 Deep | SEP-09-1990 | 5.0 | 2.5 | 18.0 | 14.3 | 15.1 | ---- |
| 1 Deep | SEP-09-1990 | ---- | ---- | ---- | ---- | ---- | 4.4 |
| 1 Deep | SEP-16-1990 | 4.5 | 3.5 | 14.6 | ---- | ---- | ---- |
| 1 Deep | SEP-16-1990 | ---- | ---- | ---- | ---- | ---- | 2.9 |
| 1 Deep | SEP-25-1990 | 5.5 | 2.0 | 23.2 | 14.4 | 15.8 | ---- |
| 1 Deep | JUN-26-1991 | 5.0 | 1.4 | 18.0 | 15.5 | 16.8 | 6.2 |
| 1 Deep | JUL-03-1991 | 4.2 | 5.2 | 17.2 | 15.7 | 16.2 | 10.1 |

| Site | Date | Trans-parency (m) | Chl *a* (ppb) | Color Pt-Co units | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Total Phos (ppb) |
|---|---|---|---|---|---|---|---|
| 1 Deep | JUL-07-1991 | ---- | ---- | ---- | ---- | ---- | 2.9 |
| 1 Deep | JUL-11-1991 | 2.5 | 7.9 | 15.5 | 15.5 | 16.3 | 7.3 |
| 1 Deep | JUL-18-1991 | 2.8 | 4.3 | 13.7 | 15.8 | 17.0 | 7.1 |
| 1 Deep | JUL-25-1991 | 3.0 | 5.7 | 18.0 | 14.8 | 15.7 | 8.6 |
| 1 Deep | JUL-31-1991 | 2.7 | 9.0 | 20.6 | 16.7 | 18.0 | 6.8 |
| 1 Deep | AUG-10-1991 | 3.5 | 5.3 | 22.3 | 15.9 | 17.6 | 8.6 |
| 1 Deep | AUG-20-1991 | 2.8 | 6.5 | 13.7 | 14.4 | 16.2 | 6.2 |
| 1 Deep | AUG-27-1991 | 4.0 | 2.9 | 18.9 | 14.6 | 15.7 | 14.1 |
| 1 Deep | SEP-08-1991 | 4.1 | 1.9 | 19.8 | 13.6 | 14.6 | 6.2 |
| 1 Deep | SEP-18-1991 | 5.0 | 2.3 | 15.5 | ---- | ---- | 5.3 |
| 1 Deep | SEP-29-1991 | ---- | ---- | ---- | ---- | ---- | 6.2 |
| 1 Deep | JUN-13-1992 | 4.8 | 1.5 | ---- | ---- | ---- | ---- |
| 1 Deep | JUN-21-1992 | 4.5 | 1.5 | 21.5 | ---- | ---- | 6.4 |
| 1 Deep | JUN-30-1992 | ---- | ---- | ---- | ---- | ---- | 9.3 |
| 1 Deep | JUL-01-1992 | 4.3 | 2.6 | 28.3 | 13.5 | 14.8 | ---- |
| 1 Deep | JUL-08-1992 | 4.0 | 2.4 | 21.5 | 13.8 | 14.6 | ---- |
| 1 Deep | JUL-18-1992 | 4.5 | 2.9 | 17.2 | 13.2 | 14.7 | ---- |
| 1 Deep | JUL-24-1992 | 4.0 | 2.4 | ---- | 14.4 | 15.0 | 6.2 |
| 1 Deep | AUG-02-1992 | 3.3 | 1.9 | 17.2 | 18.0 | 19.9 | ---- |
| 1 Deep | AUG-11-1992 | ---- | 3.1 | 28.3 | ---- | ---- | ---- |
| 1 Deep | AUG-19-1992 | 4.0 | 2.1 | 24.1 | 13.8 | 15.1 | ---- |
| 1 Deep | AUG-30-1992 | 4.0 | ---- | ---- | 13.9 | 15.0 | ---- |
| 1 Deep | SEP-13-1992 | 4.0 | 2.7 | 21.5 | 13.7 | 15.2 | ---- |
| 1 Deep | JUN-13-1993 | 3.3 | 1.8 | 16.3 | 22.4 | 24.4 | 5.6 |
| 1 Deep | JUN-20-1993 | ---- | ---- | ---- | 17.2 | 18.0 | ---- |
| 1 Deep | JUN-27-1993 | 3.8 | 2.1 | 16.3 | 16.8 | 18.8 | 7.1 |
| 1 Deep | JUL-06-1993 | 4.3 | 2.1 | 16.3 | 17.0 | 18.6 | 6.2 |
| 1 Deep | JUL-13-1993 | 3.5 | 3.1 | 17.2 | 15.5 | 17.2 | 9.9 |
| 1 Deep | JUL-19-1993 | 3.0 | 4.2 | 19.8 | 15.2 | 16.5 | 6.6 |
| 1 Deep | JUL-26-1993 | 2.8 | 4.3 | 14.6 | 15.2 | ---- | 15.4 |
| 1 Deep | AUG-02-1993 | 2.5 | 1.9 | 21.5 | 15.5 | 17.0 | ---- |
| 1 Deep | AUG-03-1993 | ---- | ---- | ---- | ---- | ---- | 12.6 |
| 1 Deep | AUG-09-1993 | 3.0 | 2.3 | 17.2 | 15.8 | 16.9 | 8.4 |
| 1 Deep | AUG-15-1993 | 3.3 | 3.2 | 18.9 | 15.4 | 17.0 | 13.0 |
| 1 Deep | AUG-22-1993 | 3.5 | 2.4 | 18.9 | 15.4 | 16.4 | 11.5 |
| 1 Deep | AUG-30-1993 | 3.0 | 1.8 | 15.5 | 14.8 | 16.3 | 6.8 |
| 1 Deep | SEP-06-1993 | 3.3 | 1.9 | 18.9 | 15.2 | 16.2 | 15.4 |
| 1 Deep | JUN-29-1994 | ---- | 1.1 | 23.2 | 14.8 | 15.8 | ---- |
| 1 Deep | JUL-06-1994 | bottom | 2.8 | 24.9 | 12.8 | 14.8 | 9.0 |
| 1 Deep | JUL-20-1994 | bottom | 1.9 | 13.7 | 13.5 | 15.5 | 13.8 |
| 1 Deep | JUL-29-1994 | bottom | ---- | 18.9 | 12.8 | 15.2 | 10.9 |
| 1 Deep | AUG-06-1994 | ---- | ---- | ---- | ---- | ---- | 9.2 |
| 1 Deep | JUN-28-1995 | 4.0 | 1.8 | 18.0 | 15.0 | 17.5 | ---- |
| 1 Deep | JUL-09-1995 | 3.5 | 2.4 | 18.9 | 16.3 | 17.4 | 5.6 |
| 1 Deep | JUL-16-1995 | 3.0 | 1.6 | 12.9 | 15.7 | 17.7 | 5.6 |
| 1 Deep | JUL-23-1995 | 3.5 | 1.9 | 19.8 | 15.6 | 17.2 | 7.1 |
| 1 Deep | JUL-30-1995 | 3.0 | 1.6 | 18.9 | 16.2 | 17.8 | 8.8 |
| 1 Deep | AUG-03-1995 | ---- | ---- | ---- | ---- | ---- | 8.1 |
| 1 Deep | AUG-08-1995 | 3.0 | 2.4 | 13.7 | ---- | ---- | 7.4 |
| 1 Deep | AUG-14-1995 | 3.5 | 1.1 | 14.6 | ---- | ---- | ---- |

| Site | Date | Trans-parency (m) | Chl *a* (ppb) | Color Pt-Co units | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Total Phos (ppb) |
|---|---|---|---|---|---|---|---|
| 1 Deep | AUG-27-1995 | 4.0 | 1.4 | 17.2 | ---- | ---- | 5.3 |
| 2 Natck | JUL-11-1985 | ---- | ---- | ---- | ---- | ---- | 5.9 |
| 2 Natck | JUL-24-1985 | ---- | ---- | ---- | ---- | ---- | 2.5 |
| 2 Natck | AUG-01-1985 | ---- | ---- | ---- | ---- | ---- | 5.6 |
| 2 Natck | AUG-09-1985 | ---- | ---- | ---- | ---- | ---- | 3.3 |
| 2 Natck | AUG-22-1985 | ---- | ---- | ---- | ---- | ---- | 158.7 |
| 2 Natck | SEP-01-1985 | ---- | ---- | ---- | ---- | ---- | 4.9 |
| 2 Natck | SEP-14-1985 | ---- | ---- | ---- | ---- | ---- | 6.1 |
| 2 Natck | SEP-21-1985 | ---- | ---- | ---- | ---- | ---- | 7.6 |
| 2 Natck | JUL-03-1986 | ---- | ---- | ---- | ---- | ---- | 4.1 |
| 2 Natck | JUL-15-1986 | ---- | ---- | ---- | ---- | ---- | 11.5 |
| 2 Natck | JUL-31-1986 | ---- | ---- | ---- | ---- | ---- | 4.1 |
| 2 Natck | AUG-10-1986 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 2 Natck | AUG-23-1986 | ---- | ---- | ---- | ---- | ---- | 2.5 |
| 2 Natck | SEP-07-1986 | ---- | ---- | ---- | ---- | ---- | 1.4 |
| 2 Natck | SEP-27-1986 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 2 Natck | OCT-25-1986 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 2 Natck | JUL-23-1987 | ---- | ---- | ---- | ---- | ---- | 16.3 |
| 2 Natck | AUG-18-1987 | ---- | ---- | ---- | ---- | ---- | 1.7 |
| 2 Natck | SEP-09-1987 | ---- | ---- | ---- | ---- | ---- | 1.3 |
| 2 Natck | JUL-03-1988 | ---- | ---- | ---- | ---- | ---- | 2.6 |
| 2 Natck | JUL-23-1988 | ---- | ---- | ---- | ---- | ---- | 4.2 |
| 2 Natck | AUG-11-1988 | ---- | ---- | ---- | ---- | ---- | 7.9 |
| 2 Natck | AUG-30-1988 | ---- | ---- | ---- | ---- | ---- | 7.1 |
| 2 Natck | JUN-14-1989 | ---- | ---- | ---- | ---- | ---- | 3.9 |
| 2 Natck | JUN-29-1989 | ---- | ---- | ---- | ---- | ---- | 9.3 |
| 2 Natck | JUL-11-1989 | ---- | ---- | ---- | ---- | ---- | 9.7 |
| 2 Natck | AUG-11-1989 | ---- | ---- | ---- | ---- | ---- | 7.9 |
| 2 Natck | AUG-30-1989 | ---- | ---- | ---- | ---- | ---- | 7.1 |
| 2 Natck | SEP-13-1989 | ---- | ---- | ---- | ---- | ---- | 7.3 |
| 2 Natck | JUL-23-1990 | ---- | ---- | ---- | ---- | ---- | 2.4 |
| 2 Natck | AUG-08-1990 | ---- | ---- | ---- | ---- | ---- | 8.4 |
| 2 Natck | SEP-09-1990 | ---- | ---- | ---- | ---- | ---- | 8.6 |
| 2 Natck | JUL-07-1991 | ---- | ---- | ---- | ---- | ---- | 7.7 |
| 2 Natck | AUG-11-1991 | ---- | ---- | ---- | ---- | ---- | 6.4 |
| 2 Natck | JUN-30-1992 | ---- | ---- | ---- | ---- | ---- | 2.4 |
| 2 Natck | JUN-13-1993 | ---- | ---- | ---- | ---- | ---- | 7.3 |
| 2 Natck | AUG-03-1993 | ---- | ---- | ---- | ---- | ---- | 9.0 |
| 2 Natck | JUL-31-1994 | ---- | ---- | ---- | ---- | ---- | 9.0 |
| 2 Natck | AUG-03-1995 | ---- | ---- | ---- | ---- | ---- | 9.4 |
| 2 Natck | AUG-27-1995 | ---- | ---- | ---- | ---- | ---- | 5.6 |
| 3 Natck | JUL-11-1985 | ---- | ---- | ---- | ---- | ---- | 5.6 |
| 3 Natck | JUL-24-1985 | ---- | ---- | ---- | ---- | ---- | 4.6 |
| 3 Natck | AUG-01-1985 | ---- | ---- | ---- | ---- | ---- | 4.6 |
| 3 Natck | AUG-09-1985 | ---- | ---- | ---- | ---- | ---- | 6.1 |
| 3 Natck | AUG-22-1985 | ---- | ---- | ---- | ---- | ---- | 5.4 |
| 3 Natck | SEP-01-1985 | ---- | ---- | ---- | ---- | ---- | 4.3 |
| 3 Natck | SEP-14-1985 | ---- | ---- | ---- | ---- | ---- | 8.4 |
| 3 Natck | SEP-21-1985 | ---- | ---- | ---- | ---- | ---- | 9.4 |
| 3 Natck | JUL-03-1986 | ---- | ---- | ---- | ---- | ---- | 11.0 |

| Site | Date | Trans-parency (m) | Chl *a* (ppb) | Color Pt-Co units | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Total Phos (ppb) |
|---|---|---|---|---|---|---|---|
| 3 Natck | JUL-15-1986 | ---- | ---- | ---- | ---- | ---- | 7.0 |
| 3 Natck | AUG-10-1986 | ---- | ---- | ---- | ---- | ---- | 6.8 |
| 3 Natck | AUG-23-1986 | ---- | ---- | ---- | ---- | ---- | 5.1 |
| 3 Natck | SEP-07-1986 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 3 Natck | SEP-27-1986 | ---- | ---- | ---- | ---- | ---- | 0.7 |
| 3 Natck | JUL-23-1987 | ---- | ---- | ---- | ---- | ---- | 86.4 |
| 3 Natck | AUG-11-1987 | ---- | ---- | ---- | ---- | ---- | 1.7 |
| 3 Natck | AUG-18-1987 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 3 Natck | SEP-09-1987 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 3 Natck | JUL-03-1988 | ---- | ---- | ---- | ---- | ---- | 3.3 |
| 3 Natck | JUL-23-1988 | ---- | ---- | ---- | ---- | ---- | 5.3 |
| 3 Natck | AUG-11-1988 | ---- | ---- | ---- | ---- | ---- | 8.8 |
| 3 Natck | AUG-30-1988 | ---- | ---- | ---- | ---- | ---- | 13.5 |
| 3 Natck | JUN-14-1989 | ---- | ---- | ---- | ---- | ---- | 9.7 |
| 3 Natck | JUL-11-1989 | ---- | ---- | ---- | ---- | ---- | 6.4 |
| 3 Natck | AUG-11-1989 | ---- | ---- | ---- | ---- | ---- | 8.8 |
| 3 Natck | AUG-30-1989 | ---- | ---- | ---- | ---- | ---- | 13.5 |
| 3 Natck | SEP-13-1989 | ---- | ---- | ---- | ---- | ---- | 7.3 |
| 3 Natck | JUL-23-1990 | ---- | ---- | ---- | ---- | ---- | 6.8 |
| 3 Natck | AUG-08-1990 | ---- | ---- | ---- | ---- | ---- | 12.8 |
| 3 Natck | SEP-09-1990 | ---- | ---- | ---- | ---- | ---- | 8.8 |
| 3 Natck | JUL-07-1991 | ---- | ---- | ---- | ---- | ---- | 6.4 |
| 3 Natck | AUG-11-1991 | ---- | ---- | ---- | ---- | ---- | 7.3 |
| 3 Natck | JUN-30-1992 | ---- | ---- | ---- | ---- | ---- | 8.8 |
| 3 Natck | JUN-13-1993 | ---- | ---- | ---- | ---- | ---- | 24.0 |
| 3 Natck | AUG-03-1993 | ---- | ---- | ---- | ---- | ---- | 358.3 |
| 3 Natck | JUL-31-1994 | ---- | ---- | ---- | ---- | ---- | 18.4 |
| 3 Natck | AUG-03-1995 | ---- | ---- | ---- | ---- | ---- | 9.6 |
| 3 Natck | AUG-27-1995 | ---- | ---- | ---- | ---- | ---- | 98.9 |
| 4 Natck | JUL-24-1985 | ---- | ---- | ---- | ---- | ---- | 2.3 |
| 4 Natck | AUG-01-1985 | ---- | ---- | ---- | ---- | ---- | 4.9 |
| 4 Natck | AUG-22-1985 | ---- | ---- | ---- | ---- | ---- | 14.7 |
| 4 Natck | SEP-01-1985 | ---- | ---- | ---- | ---- | ---- | 15.7 |
| 4 Natck | SEP-14-1985 | ---- | ---- | ---- | ---- | ---- | 20.5 |
| 4 Natck | SEP-21-1985 | ---- | ---- | ---- | ---- | ---- | 16.7 |
| 4 Natck | JUL-03-1986 | ---- | ---- | ---- | ---- | ---- | 5.5 |
| 4 Natck | JUL-15-1986 | ---- | ---- | ---- | ---- | ---- | 6.0 |
| 4 Natck | AUG-10-1986 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 4 Natck | AUG-23-1986 | ---- | ---- | ---- | ---- | ---- | 3.4 |
| 4 Natck | SEP-07-1986 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 4 Natck | SEP-27-1986 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 4 Natck | JUL-23-1987 | ---- | ---- | ---- | ---- | ---- | 30.0 |
| 4 Natck | AUG-11-1987 | ---- | ---- | ---- | ---- | ---- | 3.3 |
| 4 Natck | AUG-18-1987 | ---- | ---- | ---- | ---- | ---- | 3.0 |
| 4 Natck | SEP-09-1987 | ---- | ---- | ---- | ---- | ---- | 3.0 |
| 4 Natck | JUL-03-1988 | ---- | ---- | ---- | ---- | ---- | 3.3 |
| 4 Natck | JUL-12-1988 | ---- | ---- | ---- | ---- | ---- | 10.4 |
| 4 Natck | AUG-11-1988 | ---- | ---- | ---- | ---- | ---- | 19.0 |
| 4 Natck | AUG-30-1988 | ---- | ---- | ---- | ---- | ---- | 19.2 |
| 4 Natck | JUN-14-1989 | ---- | ---- | ---- | ---- | ---- | 7.3 |

| Site | Date | Trans-parency (m) | Chl *a* (ppb) | Color Pt-Co units | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Total Phos (ppb) |
|---|---|---|---|---|---|---|---|
| 4 Natck | JUL-11-1989 | ---- | ---- | ---- | ---- | ---- | 11.7 |
| 4 Natck | AUG-11-1989 | ---- | ---- | ---- | ---- | ---- | 19.0 |
| 4 Natck | AUG-30-1989 | ---- | ---- | ---- | ---- | ---- | 19.2 |
| 4 Natck | SEP-13-1989 | ---- | ---- | ---- | ---- | ---- | 12.6 |
| 4 Natck | JUL-23-1990 | ---- | ---- | ---- | ---- | ---- | 3.9 |
| 4 Natck | AUG-08-1990 | ---- | ---- | ---- | ---- | ---- | 8.4 |
| 4 Natck | SEP-09-1990 | ---- | ---- | ---- | ---- | ---- | 4.0 |
| 4 Natck | JUL-07-1991 | ---- | ---- | ---- | ---- | ---- | 12.3 |
| 4 Natck | AUG-11-1991 | ---- | ---- | ---- | ---- | ---- | 15.4 |
| 4 Natck | AUG-20-1991 | ---- | ---- | ---- | ---- | ---- | 7.9 |
| 4 Natck | JUN-30-1992 | ---- | ---- | ---- | ---- | ---- | 21.6 |
| 4 Natck | JUL-18-1992 | ---- | ---- | ---- | ---- | ---- | 8.8 |
| 4 Natck | JUL-18-1992 | ---- | ---- | ---- | ---- | ---- | 8.8 |
| 4 Natck | JUN-13-1993 | ---- | ---- | ---- | ---- | ---- | 6.6 |
| 4 Natck | AUG-03-1993 | ---- | ---- | ---- | ---- | ---- | 54.0 |
| 4 Natck | JUL-31-1994 | ---- | ---- | ---- | ---- | ---- | 9.9 |
| 4 Natck | AUG-03-1995 | ---- | ---- | ---- | ---- | 9.1 | 9.1 |
| 4 Natck | AUG-27-1995 | ---- | ---- | ---- | ---- | ---- | 5.8 |
| 5 Natck | AUG-11-1987 | ---- | ---- | ---- | ---- | ---- | 3.0 |
| 5 Natck | AUG-18-1987 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 5 Natck | AUG-25-1987 | ---- | ---- | ---- | ---- | ---- | 1.7 |
| 5 Natck | SEP-09-1987 | ---- | ---- | ---- | ---- | ---- | 2.7 |
| 5 Natck | SEP-18-1987 | ---- | ---- | ---- | ---- | ---- | 1.3 |
| 5 Natck | SEP-21-1987 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 5 Natck | SEP-27-1987 | ---- | ---- | ---- | ---- | ---- | 2.7 |
| 5 Natck | JUL-03-1988 | ---- | ---- | ---- | ---- | ---- | 15.2 |
| 5 Natck | AUG-30-1988 | ---- | ---- | ---- | ---- | ---- | 6.8 |
| 5 Natck | JUN-14-1989 | ---- | ---- | ---- | ---- | ---- | 4.2 |
| 5 Natck | JUN-29-1989 | ---- | ---- | ---- | ---- | ---- | 5.5 |
| 5 Natck | JUL-04-1989 | ---- | ---- | ---- | ---- | ---- | 4.4 |
| 5 Natck | AUG-30-1989 | ---- | ---- | ---- | ---- | ---- | 6.8 |
| 5 Natck | SEP-13-1989 | ---- | ---- | ---- | ---- | ---- | 5.1 |
| 5 Natck | JUL-23-1990 | ---- | ---- | ---- | ---- | ---- | 4.9 |
| 5 Natck | AUG-08-1990 | ---- | ---- | ---- | ---- | ---- | 3.5 |
| 5 Natck | SEP-09-1990 | ---- | ---- | ---- | ---- | ---- | 3.1 |
| 5 Natck | JUL-07-1991 | ---- | ---- | ---- | ---- | ---- | 7.1 |
| 5 Natck | AUG-11-1991 | ---- | ---- | ---- | ---- | ---- | 6.0 |
| 5 Natck | JUN-30-1992 | ---- | ---- | ---- | ---- | ---- | 12.8 |
| 5 Natck | JUN-13-1993 | ---- | ---- | ---- | ---- | ---- | 11.7 |
| 5 Natck | AUG-03-1993 | ---- | ---- | ---- | ---- | ---- | 38.4 |
| 5 Natck | JUL-31-1994 | ---- | ---- | ---- | ---- | ---- | 30.5 |
| 5 Natck | AUG-03-1995 | ---- | ---- | ---- | ---- | ---- | 25.1 |
| 5 Natck | AUG-27-1995 | ---- | ---- | ---- | ---- | ---- | 9.9 |
| 6 Natck | SEP-21-1987 | ---- | ---- | ---- | ---- | ---- | 1.7 |
| 6 Natck | SEP-27-1987 | ---- | ---- | ---- | ---- | ---- | 2.0 |
| 6 Natck | JUL-03-1988 | ---- | ---- | ---- | ---- | ---- | 2.6 |
| 6 Natck | JUL-12-1988 | ---- | ---- | ---- | ---- | ---- | 4.2 |
| 6 Natck | AUG-30-1988 | ---- | ---- | ---- | ---- | ---- | 30.0 |
| 6 Natck | JUN-14-1989 | ---- | ---- | ---- | ---- | ---- | 14.8 |
| 6 Natck | JUL-11-1989 | ---- | ---- | ---- | ---- | ---- | 116.9 |

| Site | Date | Trans-parency (m) | Chl *a* (ppb) | Color Pt-Co units | Alk. (gray) ph 5.1 | Alk. (pink) ph 4.6 | Total Phos (ppb) |
|---|---|---|---|---|---|---|---|
| 6 Natck | AUG-30-1989 | ---- | ---- | ---- | ---- | ---- | 2.3 |
| 6 Natck | SEP-13-1989 | ---- | ---- | ---- | ---- | ---- | 10.1 |
| 6 Natck | AUG-08-1990 | ---- | ---- | ---- | ---- | ---- | 6.0 |
| 6 Natck | SEP-09-1990 | ---- | ---- | ---- | ---- | ---- | 4.2 |
| 6 Natck | JUL-07-1991 | ---- | ---- | ---- | ---- | ---- | 7.7 |
| 6 Natck | AUG-11-1991 | ---- | ---- | ---- | ---- | ---- | 27.3 |
| 6 Natck | AUG-20-1991 | ---- | ---- | ---- | ---- | ---- | 3.3 |
| 6 Natck | JUN-30-1992 | ---- | ---- | ---- | ---- | ---- | 6.2 |
| 6 Natck | JUN-13-1993 | ---- | ---- | ---- | ---- | ---- | 11.7 |
| 6 Natck | AUG-03-1993 | ---- | ---- | ---- | ---- | ---- | 15.2 |
| 6 Natck | JUL-31-1994 | ---- | ---- | ---- | ---- | ---- | 15.7 |
| 6 Natck | AUG-27-1995 | ---- | ---- | ---- | ---- | ---- | 17.5 |
| 7 Natck | AUG-03-1995 | ---- | ---- | ---- | ---- | ---- | 19.5 |
| 7 Natck | AUG-27-1995 | ---- | ---- | ---- | ---- | ---- | 7.9 |
| No Label! | JUL-02-1985 | ---- | ---- | ---- | ---- | ---- | 7.1 |

# Naticook Lake -August 13, 1996

## Light Data (presented as relative % light penetration)

| Site | Depth (m | Relative | Ln (light) |
|---|---|---|---|
| 1 Deep | 0.1 | 100 | 4.61 |
| 1 Deep | 0.5 | 58 | 4.06 |
| 1 Deep | 1 | 40 | 3.69 |
| 1 Deep | 1.5 | 30 | 3.40 |
| 1 Deep | 2 | 23 | 3.14 |
| 1 Deep | 2.5 | 19 | 2.94 |
| 1 Deep | 3.01 | 15 | 2.71 |
| 1 Deep | 3.52 | 12 | 2.48 |
| 1 Deep | 4.025 | 9 | 2.20 |
| 1 Deep | 4.53 | 6.2 | 1.82 |
| 1 Deep | 5.037 | 3.8 | 1.34 |
| 1 Deep | 5.54 | 2 | 0.69 |

**Depth: 0.1-5.5 meters**

Regression Output:

| | |
|---|---|
| Constant | 4.4757 |
| Std Err of Y Est | 0.1861 |
| R Squared | 0.9755 |
| No. of Observations | 12 |
| Degrees of Freedom | 10 |
| X Coefficient(s) | **-0.6202 slope** |
| Std Err of Coef. | 0.0311 |

**Depth: 0.5- 4.0 meters**

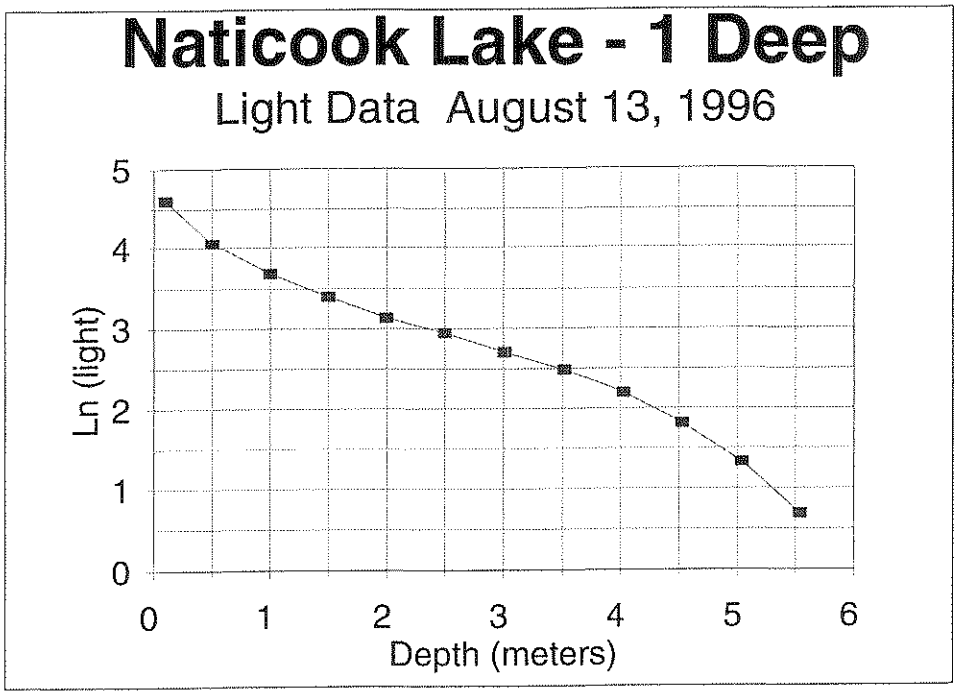
Regression Output:

| | |
|---|---|
| Constant | 4.215 |
| Std Err of Y Est | 0.059 |
| R Squared | 0.992 |
| No. of Observations | 8 |
| Degrees of Freedom | 6 |
| X Coefficient(s) | **-0.5041 slope** |
| Std Err of Coef. | 0.018 |

**Depth: 4.0 - 5.5 meters**

Regression Output:

| | |
|---|---|
| Constant | 6.2474 |
| Std Err of Y Est | 0.0961 |
| R Squared | 0.9854 |
| No. of Observations | 4 |
| Degrees of Freedom | 2 |
| X Coefficient(s) | **-0.9899 slope** |
| Std Err of Coef. | 0.0851 |



# APPENDIX B

**NHDES Technical Bulletin** **WSPCD-WU-1996-8**

## Comprehensive Shoreland Protection Act, RSA 483-B

## *Minimum Shoreland Protection Standards*

### LIMITS WITHIN THE PROTECTED SHORELAND (250 ft)

* Prohibited Uses:
  - Establishment/expansion of salt storage yards, auto junk yards, solid waste & hazardous waste facilities.
  - Use of fertilizer, except limestone, within 25 feet of the reference line. Low phosphate, slow release nitrogen fertilizer allowed beyond 25 foot zone.

* Uses Requiring State Permits:
  - Public water supply facilities
  - Public water & sewage treatment facilities
  - Public utility lines
  - Existing solid waste facilities
  - All activities regulated by the DES Wetlands Bureau per RSA 482-A

### OTHER RESTRICTED USES

- All new lots, including those in excess of 5 acres, are subject to subdivision approval by DES.
- Setback requirements for all of new septic systems are determined by soil characteristics.
- Minimum lot size in areas dependent on septic systems determined by soil type.
- Alteration of Terrain Permit standards reduced from 100,000 square feet to 50,000 square feet.
- Total number of residential units in areas dependent on on-site sewage & septic systems, not to exceed 1 unit per 150 feet of shoreland frontage.

### NATURAL WOODLAND BUFFER RESTRICTIONS (150 ft)

- Where existing, a natural woodland buffer must be maintained.
- Tree cutting limited to 50% of the basal area of trees, and 50% of the total number of saplings in a 20 year period. A healthy, well-distributed stand of trees must be maintained.
- Stumps and their root systems must remain intact in the ground within 50 feet of the reference line.

## NEW SEPTIC SYSTEM LEACHFIELD SETBACKS (75 - 125 ft)

- 125 feet where soil down gradient of leachfield is porous sand & gravel.
- 100 feet where soil maps indicate presence of soils with restrictive layers within 18 inches of natural soil surface.
- 75 feet where soil map indicates presence of all other soil types.
- 75 feet minimum setback from rivers.

## PRIMARY BUILDING LINE* (50 ft)

- Primary buildings setback behind line.

## REFERENCE LINE

- For coastal waters = highest observable tide line
- For rivers = ordinary high water mark
- For natural fresh water bodies = natural mean high water level
- For artificially impounded fresh water bodies = water line at full pond

*** If a municipality establishes a shoreland setback for primary buildings, whether greater or lesser than 50 feet, that defines the Primary Building Line for that municipality.**

***Note: The Comprehensive Shoreland Protection Act is subject to revisions. You should contact the Shoreland Protection Act coordinator, Natilie Landry (271-2658), for the latest modifications to the act or if you need any further information.***

# APPENDIX C

## GLOSSARY OF LIMNOLOGICAL TERMS

**Aerobe**- Organisms requiring oxygen for life. All animals, most algae and some bacteria require oxygen for respiration.

**Algae**- See phytoplankton.

**Alkalinity**- Total concentration of bicarbonate and hydroxide ions (in most lakes).

**Anaerobe**- Organisms not requiring oxygen for life. Some algae and many bacteria are able to respire or ferment without using oxygen.

**Anoxic**- A system lacking oxygen, therefore incapable of supporting the most common kind of biological respiration, or of supporting oxygen-demanding chemical reactions. The deeper waters of a lake may become anoxic if there are many organisms depleting oxygen via respiration, and there is little or no replenishment of oxygen from photosynthesis or from the atmosphere.

**Benthic**- Referring to the bottom sediments.

**Bacterioplankton**- Bacteria adapted to the "open water" or "planktonic" zone of lakes, adapted for many specialized habitats and include groups that can use the sun's energy (phytoplankton), some that can use the energy locked in sulfur or iron, and others that gain energy by decomposing dead material.

**Bicarbonate**- The most important ion (chemical) involved in the buffering system of New Hampshire lakes.

**Buffering**- The capacity of lakewater to absorb acid with a minimal change in the pH. In New Hampshire the chemical responsible for buffering is the bicarbonate ion. (See pH.)

**Chloride**- One of the components of salts dissolved in lakewater. Generally the most abundant ion in New Hampshire lakewater, it may be used as an indicator of raw sewage or of road salt.

**Chlorophyll a**- The main green pigment in plants. The concentration of chlorophyll *a* in lakewater is often used as an indicator of algal abundance.

**Circulation**- The period during spring and fall when the combination of low water temperature and wind cause the water column to mix freely over its entire depth.

**Density**- The weight per volume of a substance. The more dense an object, the heavier it feels. Low-density liquids will float on higher-density liquids.

**Dimictic**- The thermal pattern of lakes where the lake circulates, or mixes, twice a year. Other patterns such as polymictic (many periods of circulation per year) are uncommon in New Hampshire. (See also meromictic and holomictic).

**Dystrophy**- The lake trophic state in which the lakewater is highly stained with humic acids (reddish brown or yellow stain) and has low productivity. Chlorophyll *a* concentration may be low or high.

**Epilimnion**- The uppermost layer of water during periods of thermal stratification. (See lake diagram).

**Eutrophy**- The lake trophic state in which algal production is high. Associated with eutrophy is low Secchi Disk depth, high chlorophyll *a*, and high total phosphorus. From an esthetic viewpoint these lakes are "bad" because water clarity is low, aquatic plants are often found in abundance, and cold-water fish such as trout and salmon are usually not present. A good aspect of eutrophic lakes is their high productivity in terms of warm-water fish such as bass, pickerel, and perch.

**Free CO2**- Carbon dioxide that is not combined chemically with lake water or any other substances. It is produced by respiration, and is used by plants and bacteria for photosynthesis.

**Holomixis**- The condition where the entire lake is free to circulate during periods of overturn. (See meromixis.)

**Humic Acids**- Dissolved organic compounds released from decomposition of plant leaves and stems. Humic acids are red, brown, or yellow in color and are present in nearly all lakes in New Hampshire. Humic acids are consumed only by fungi, and thus are relatively resistant to biological decomposition.

**Hydrogen Ion**- The "acid" ion, present in small amounts even in distilled water, but contributed to rain-water by atmospheric processes, to ground-water by soils, and to lakewater by biological organisms and sediments. The active component of "acid rain". See also "pH" the symbolic value inversely and exponentially related to the hydrogen ion.

**Hypolimnion**- The deepest layer of lakewater during periods of thermal stratification. (See lake diagram)

**Lake**- Any "inland" body of relatively "standing" water. Includes many synonyms such as ponds, tarns, loches, billabongs, bogs, marshes, etc.

**Lake Morphology**- The shape and size of a lake and its basin.

**Littoral**- The area of a lake shallow enough for submerged aquatic plants to grow.

**Meromixis**- The condition where the entire lake fails to circulate to its deepest points; caused by a high concentration of salt in the deeper waters, and by peculiar landscapes (small deep lakes surrounded by hills and/or forests. (Contrast holomixis.)

**Mesotrophy**- The lake trophic state intermediate between oligotrophy and eutrophy. Algal production is moderate, and chlorophyll *a*, Secchi Disk depth, and total phosphorus are also moderate. These lakes are esthetically "fair" but not as good as oligotrophic lakes.

**Metalimnion**- The "middle" layer of the lake during periods of summer thermal stratification. Usually defined as the region where the water temperature changes at least one degree per meter depth. Also called the thermocline.

**Mixis**- Periods of lakewater mixing or circulation.

**Mixotrophy**- The lake condition where the water is highly stained with humic acids, but algal production and chlorophyll *a* values are also high.

**Oligotrophy**- The lake trophic state where algal production is low, Secchi Disk depth is deep, and chlorophyll *a* and total phosphorus are low. Esthetically these lakes are the "best" because they are clear and have a minimum of algae and aquatic plants. Deep oligotrophic lakes can usually support cold-water fish such as lake trout and land-locked salmon.

**Overturn**- See circulation or mixis

**pH**- A measure of the hydrogen ion concentration of a liquid. For every decrease of 1 pH unit, the hydrogen ion concentration increases 10 times. Symbolically, the pH value is the "negative logarithm" of the hydrogen ion concentration. For example, a pH of 5 represents a hydrogen ion concentration of $10^{-5}$ molar. [Please thank the chemists for this lovely symbolism -- and ask them to explain it in lay terms!] In any event, the higher the pH value, the lower the hydrogen ion concentration. The range is 0 to 14, with 7 being neutral 1 denoting high acid condition and 14 denoting very basic condition.

**Photosynthesis**- The process by which plants convert the inorganic substances carbon dioxide and water into organic glucose (sugar) and oxygen using sunlight as the energy source. Glucose is an energy source for growth, reproduction, and maintenance of almost all life forms.

**Phytoplankton**- Microscopic algae which are suspended in the "open water" zone of lakes and ponds. A major source of food for zooplankton. Common examples include: diatoms, euglenoids, dinoflagellates, and many others. Usually included are the blue-green bacteria.

**Parts per million**- Also known as "ppm". This is a method of expressing the amount of one substance (solute) dissolved in another (solvent). For example, a solution with 10 ppm of oxygen has 10 pounds of oxygen for every 999,990 pounds (500 tons) of water. Domestic sewage usually contains from 2 to 10 ppm phosphorus.

**Parts per billion**-Also known as "ppb". This is only 1/1000 of ppm, therefore much less concentrated. As little as 1 ppb of phosphorus will sustain growth of algae. As little as 10 ppb phosphorus will cause algal blooms! Think of the ratio as 1 milligram (1/28000 of an ounce) of phosphorus in 25 barrels of water (55 gallon drums)! Or, 1 gallon of septic waste diluted into 10,000 gallons of lakewater. It adds up fast!

**Plankton**- Community of microorganisms that live suspended in the water column, not attached to the bottom sediments or aquatic plants. See also "bacterioplankton" (bacteria), "phytoplankton" (algae) and "zooplankton" (microcrustaceans and rotifers).

**Saturated**- When a solute (such as water) has dissolved all of a substance that it can. For example, if you add table salt to water, a point is reached where any additional salt fails to dissolve. The water is then said to be saturated with table salt. In lakewater, gaseous oxygen can dissolve, but eventually the water becomes saturated with oxygen if exposed sufficiently long to the atmosphere or another source of oxygen.

**Specific Conductivity**- A measure of the amount of salt present in lakewater. As the salt concentration increases, so does the specific conductivity (electrical conductivity).

**Stratum**- A layer or "blanket". Can be used to refer to one of the major layers of lakewater such as the epilimnion, or to any layers of organisms or chemicals that may be present in a lake.

**Thermal Stratification**- The process by which layers are built up in the lake due to heating by the sun and partial mixing by wind.

**Thermocline**- Region of temperature change. (See metalimnion.)

**Total Phosphorus**- A measure of the concentration of phosphorus in lakewater. Includes both free forms (dissolved), and chemically combined form (as in living tissue, or in dead but suspended organisms).

**Trophic Status**- A classification system placing lakes into similar groups according to their amount of algal production. (See Oligotrophy, Mesotrophy, Eutrophy, Mixotrophy, and Dystrophy for definitions of the major categories)

**Z**- A symbol used by limnologists as an abbreviation for depth.

**Zooplankton**- Microscopic animals in the planktonic community. Some are called "water fleas", but most are known by their scientific names. Scientific names include: *Daphnia*, *Cyclops*, *Bosmina*, and *Kellicottia*.