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**April 26, 1997**

# RESULTS FROM THE 1996-1997 WISCONSIN-DNR PLANNING GRANT

## SUBMITTED BY C.J. OWEN AND ASSOCIATES

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# FIELD MONITORING METHODS USED FOR THE DIAGNOSTIC STUDY OF LAKE AMNICON/DOWLING: 1996-1997

Photo: C.J. Owen and Associates

## Introduction and Grant Criteria

The following project summary is presented by C.J. Owen and Associates to the Lake Amnicon and Dowling Lakes Management and Sanitary District. The project was funded by a Wisconsin DNR 1996-1997 Lake Management Planning Grant Program Grant. The planning grants are intended to provide funding for the lake management ***planning*** process. Up to $10,000 per project and a maximum of $50,000 is available at a 75% state cost share. The intent of the project is to help ***develop*** comprehensive management plans depending on the condition and needs of the lake (which the planning process will help determine). The plan will specify activities related to minimizing the impacts of future development, managing user conflicts, improving fishing or improving water quality.

The current project focuses on developing long term management activities to help maintain the health of the lake. In an effort to address this focus, analysis of water quality parameters have considered the whole lake as a potentially impacted resource, influenced by the entire community within the lake(s) watershed. Results from the inlake studies of 1994, 1995 and this report should be characterized as an overall community concern to be addressed. It should not be interpreted as indicating individual(s) responsibilities for a given source of impact from a geographical area. Resources are not available to assess each individual on quantifiable impacts to the water quality of the lakes, rather the data suggests possible avenues by which the whole community my be impacting the water resource.

The intent of the grant process is to develop a holistic approach to watershed management and should not focus on one perceived problem area. This is the case for the current and previous planning grants in that, although of concern to the district members, the focus should not be solely on septic issues but rather should be considered in the context of the continuation of the monitoring of water quality in Lake Amnicon and Dowling, of which groundwater (impacted by several factors including wastewater disposal) entering the lake is only one part.

When using the data generated by these studies it should be recognized that the focus of the sampling design is on protection of the health of the lake (i.e. the processes that effect how rapidly the lake ages-eutrophication-and the "usability" of the water resource for humans as well as animals). However, some of the data gathered may be taken into consideration when analyzing possible impacts on the health and well being of the people utilizing the lakes.

## Monitoring-Field

All in-lake monitoring for this project was carried out between May 11, 1996 and January 25, 1997. Monitoring and sampling were conducted by C.J. Owen and Associates.

## Study Lakes

Amnicon Lake is located in west central Douglas County, Wisconsin. Amnicon is a 172.4 hectare, relatively shallow (maximum depth 9.5 meters; mean depth 3 meter) drainage lake of glacial origin. Shoreline distance (not including two state owned islands) is 8.22 kilometers. Lake volume is approximately 5,200,000 cubic meters. The trophic status of Lake Amnicon is eutrophic (*1993, 1994 and 1995 final report by C.J. Owen and Associates*). The shoreline of Amnicon is characterized as heavily developed, containing 2 and 3 tier development. One hundred and forty-eight shoreline lots were observed in 1994, resulting in a ratio of twenty-nine lots per shoreline mile. There are three (3) public boat launches and one campground on the lake.

Dowling Lake is adjacent to Amnicon Lake in west central Douglas County, Wisconsin. Dowling is a 62.24 hectare, shallow (maximum depth of 3.96 meters; mean depth 2.13 meters), drainage lake. Dowling is the major inflow to Amnicon Lake. Shoreline distance (not including islands) is 3.14 kilometers. The lake volume is approximately 1,400,000 cubic meters. The trophic status of Lake Dowling is eutrophic

(*1993 and 1994 reports by C.J. Owen and Associates*). The shoreline of Dowling is characterized as heavily developed, containing 2 and 3 tier development. Eighty-two shoreline lots were observed in 1994 resulting in 41 lots per shoreline mile. There is one (1) public boat launch and no campgrounds on Dowling. (Appendix 1: Map 1 and 2).

## Sampling Methodology

Water temperature, dissolved oxygen concentration and specific conductivity at each sampling site were measured at one meter intervals. Secchi disk transparency was also recorded at each site. Samples of the epilimnion (shallow sample), collected for chemical and biological analysis, were sampled 1 meter below the surface using a Van Dorn sampler. In addition to surface samples, maximum depth samples were also collected using a Van Dorn sampler. The deep samples were collected 1 meter off the bottom (the bottom of the hypolimnion). Phytoplankton samples were taken from the epilimnetic sample for identification.

### *Bacteria*

Hot spot bacterial sampling consisted of dip samples collected by inverting the bottle (neck-down) in the water and inverting to fill, 6 in. below the surface of the water. All bacterial samples were collected away from the edge of the boat using a gloved hand technique. Samples were packaged on ice and delivered to the Wisconsin Department of Hygiene's laboratory for analysis. Samples were sent by UPS overnight service .

### *Phytoplankton*

Whole water samples were collected and immediately preserved with Lugol's iodine. Sample date, location, and depth were noted. 20 mls of sample was layered over 10-15 mls of deionized water in a Utermohl-type settling chamber (cylinder towers 97mm high x 25 mm diameter, slide chamber 25 mm dia.). Samples were allowed to settle, undisturbed, for 24 hrs.

The entire slide chamber was scanned at 200X and 400X with an Olympus IMT inverted microscope and genera and species (if possible) were identified and listed. Unidentified forms were also recorded and general morphological characteristics noted. Other morphological characteristics including Cyanobacteria akinetes and heterocysts and Chrysophyte statospores were also noted. Percent contribution to community biomass was determined for each species by considering size, growth form and abundance. A scan at 100X aided in this estimation.

### *Field Methods-Chemical Samples*

Field measurement and sample collection were carried out using routine limnological practices (Kallar et al. 1981; Lind 1985; EPA 1989). Temperature, dissolved oxygen , and conductivity were measured with a YSI 58 probe. All probes were calibrated with standard reference solutions prior to each sampling period. In the field, probes were lowered to the designated depth and allowed to equilibrate before measurements were recorded. Profiles were taken bi-monthly from May until January.

Water transparency for the lake was measured using a standard 20 cm diameter Secchi disk. Occasional photosynthetically active radiation (PAR) measurements were taken using a Licor FI-1000 Data Logger light meter equipped with a LI-190-SA and LI-192-SA quantum sensors.

Discrete samples were collected with a four-liter PVC Van Dorn water sampler. Samples were placed in pre-labeled polyethylene bottles containing the sampling date, lake name, site number and depth (provided by the State Laboratory of Hygiene). Samples were preserved according to instructions provided by the State Laboratory of Hygiene and placed into coolers and kept dark and chilled during transport to the laboratory by overnight express UPS.

### *Groundwater Sampling*

In order to determine flow direction and quality, 36 observation wells were installed in the Amnicon-Dowling area in 1979. These wells were clustered in groups of two or three (a shallow lowland well, a shallow upland well and at six sites a deep lowland well) at 15 locations around the lake as part of the 1978-1979 Lake Amnicon and Dowling study (WI-DNR, 1980). Permeability was quite varied due to the unsorted glacial deposits. The maximum permeability was 117 gallon/square foot/day and was measured at the well site "J-lowland", located in the populated north shore of Amnicon Lake. At the time standard practice was to filter samples in the lab just prior to analysis (WI-DNR, 1980). This practice resulted in loss of soluble phosphorus (greater than 80%) due to reactions with iron and manganese under oxygenated conditions. On May 27-28, 1996 C.J Owen and Associates attempted to locate and sample the "lowland" wells at eight sites on Amnicon Lake and six on Dowling Lake using procedures developed to minimize unwanted chemical reactions.

Twenty-eight seepage meters with a modified design of Lee (1972) were constructed and deployed in Lake Amnicon and Lake Dowling on June 28, 1996. Seepage meters were sampled on July 14 and September 22, 1996 relying on adequate flow rates to fill the volume necessary to perform required analysis. The duration of deployment for the first sampling was seven days. The second sampling was taken after 26 days. Flow rates decreased significantly over the summer, only allowing for two samplings during the field season. Seepage meters were constructed of 0.35 meter diameter plastic "bowl" catch basins. A 20 cm. x 2 cm. polyvinyl chloride collection tube was inserted through the top of the meters using water proof fittings. Meters were slowly inserted into the lake sediment in 0.5-1.0 meters of water. Depth of sediment penetration did not exceed 10 cm. Meters were installed at a slight angle to promote flow towards the collection system and to allow gas released from the sediments to escape through the unsealed collection tube. Meters were left un-bagged for a minimum of seven days prior to securing the collection bags to the collection tube. This allowed for complete flushing of lake water from the collection system and to allow benthic organisms to escape.

Thick plastic collection bags were secured to the system using plastic quick release clamps. Care was taken to insure that the bags had adequate expansion, with low resistance to flow. Bags were sampled by twisting the bag above the clamp to limit the exposure of the sample to ambient air and lake water. Samples were then transferred into pre-preserved sampling bottles, chilled and shipped via overnight UPS to the Wisconsin Department of Health State Laboratory of Hygiene for analysis.

## PHYSICAL AND CHEMICAL RESULTS FOR THE 1996-1997 LAKE AMNICON/DOWLING STUDY

### Dissolved Oxygen and Temperature Profiles

Dissolved oxygen (DO) concentrations range between 0 and 14 mg/L in most Wisconsin lakes. Of concern to lake managers is the summer level of DO in the hypolimnion. A rapid depletion of DO may indicate high rates of decomposition of organic matter in the hypolimnion which results from a high rate of primary productivity in the epilimnion. A lake with an anoxic (no oxygen) hypolimnion and thermal stratification by early July, is probably eutrophic. Conversely, a lake with substantial levels of DO (over 5 mg/L) throughout its hypolimnion until late August, despite stable stratification, is probably oligotrophic.

Photo: C.J. Owen and Associates

The early development of hypolimnetic anoxia may result from the following:

- Increased algal growth due to increased nutrient loading causing increased carbonaceous DO depletion.
- Increased $NH_4$ inputs that exert their own nitrogenous biochemical oxygen demand (N-BOD) associated with nitrification.
- Organic matter washing in from shoreline erosion, road runoff, septic fields as well as decomposing organic material that cause the rapid depletion of hypolimnetic oxygen.

In these types of productive lakes a high rate of DO depletion can cause a temperature-DO "squeeze" in which habitat for cool water fish is severely restricted because the necessary thermal habitat is anoxic (Coutant 1984).

The objective for bi-monthly DO and temperature profiles in Lake Amnicon/Dowling was to:

1) determine an accurate date for the onset of hypolimnetic anoxia for the lakes;

Because of the behavior of water, many lakes in temperate climates tend to stratify, or form layers, especially during the summer. In spring, just before a lake's ice cover melts, the water near the bottom will be at ~4°C (temperature at which water reaches maximum density). Water above will be cooler, approaching 0°C just under the ice. As warming occurs and the ice melts, the surface water heats up (increasing in density), sinks and eventually results in the entire water column becoming isothermal or uniform at 4°C. When surface water temperature is equivalent to the temperature of the bottom water, complete wind mixing will occur. As the season progresses, surface water then begins to warm (decreasing its density) and eventually this less dense water may not be able to penetrate the more dense (cooler) bottom water. The inverse process may occur in the fall with surface cooling and whole lake mixing. This pattern of spring over-turn, summer stratification and fall over-turn is typical of deeper temperate lakes that develop a winter ice cover. Lakes with this pattern of two mixing periods are referred to as dimictic. Many shallow lakes, however, do not stratify in the summer or stratify for only short periods of time. Lakes that stratify and de-stratify numerous times during the summer are known as polymictic lakes. Both polymictic and dimictic lakes are common in Wisconsin.

## Lake Amnicon Dissolved Oxygen and Temperature Results

### *Lake Amnicon*

The May 19 sampling was performed during spring over-turn as indicated by isothermal conditions with oxygen saturated throughout the water column. These results indicate a system without thermal stratification, susceptible to event-induced re-oxygenation (i.e. wind mixing-Figure 1).

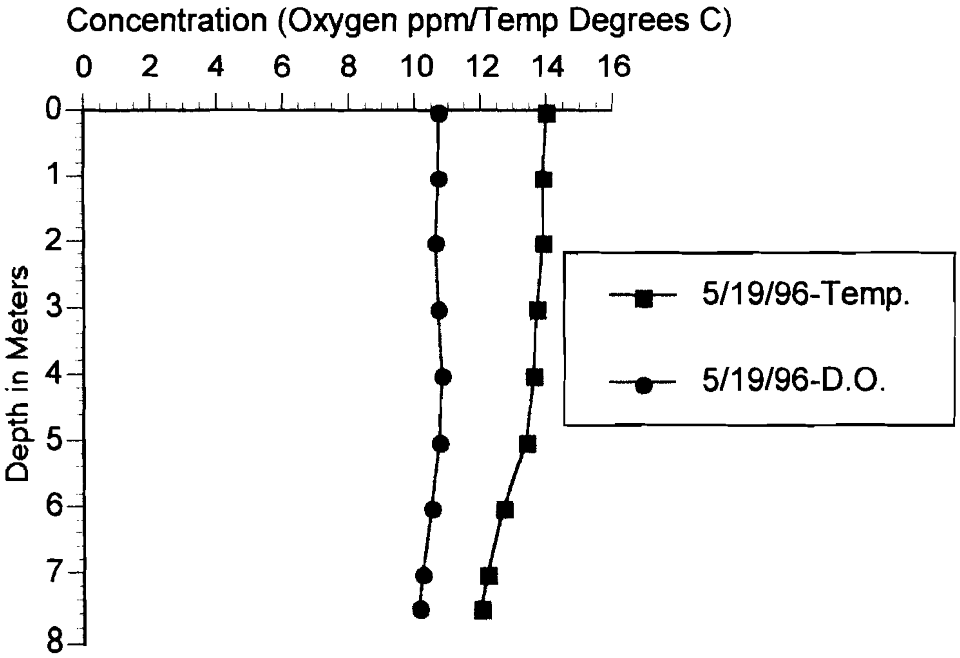


Figure 1. Lake Amnicon Dissolved Oxygen/Temperature profile.

June 9th sampling indicated a system with surface water warming and relatively weak thermal stratification. DO concentrations were saturated at the surface with a gradual rate of depletion below 4 meters to 7 ppm from 4-7 meters. June 22nd sampling indicates a stronger thermal stratification and a drop in surface water DO saturation. DO levels continued the sharp depletion at 4 meters to below 2 ppm at 6 meters (Figure 2).

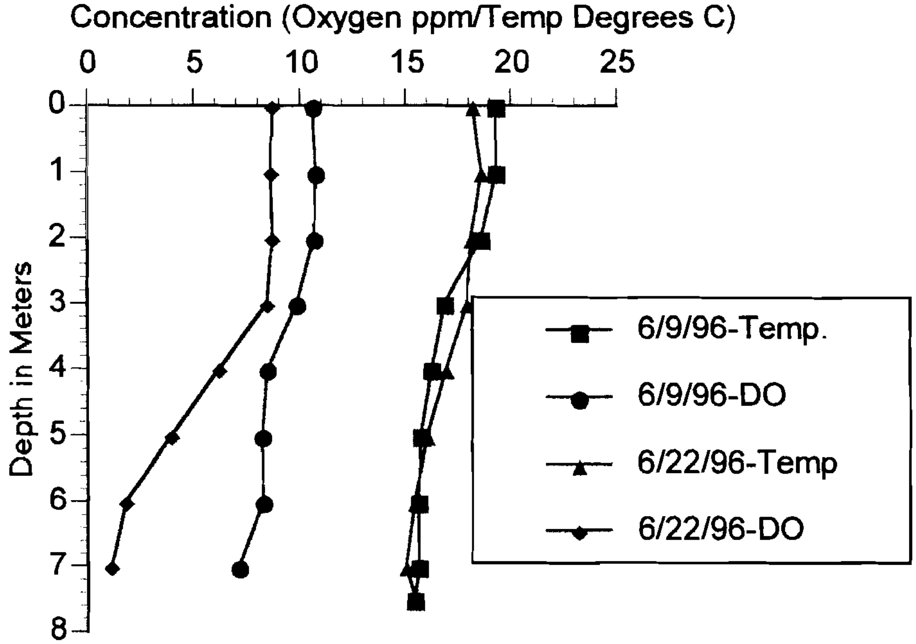


Figure 2. Lake Amnicon Dissolved Oxygen/Temperature profile.

July sampling indicates rapid surface water warming to above 20°C on July 14th. The water column was weakly stratified, with a defined thermocline at 5 meters. First date of complete hypolimnetic anoxia occurred between the first July sampling (7/14/96) and the last (7/30/96). A significant portion of the water column was below 5 ppm during both the July 14th and 30th sampling (Figure 3).

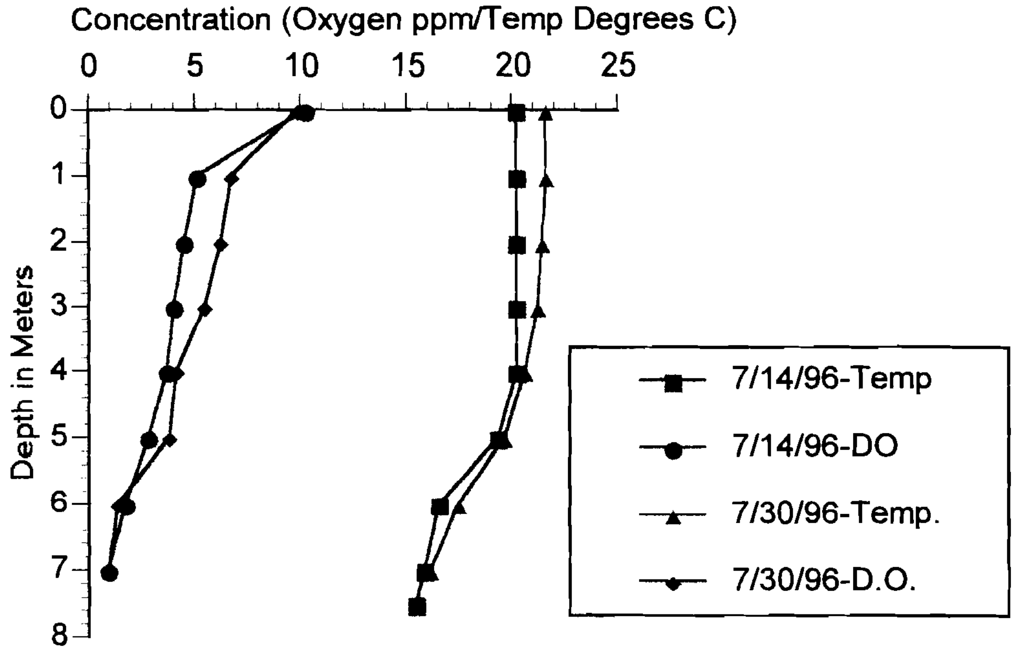


Figure 3. Lake Amnicon Dissolved Oxygen/Temperature profile.

August profiles indicate continued surface water warming to above 23°C on August 12th . The lake system is weakly thermally stratified with ~ 0 ppm DO below 6 meters on 8/12/96. This is of some concern to the cold water fisheries in the lake because the needed cold water is low in needed oxygen (Figure 4).

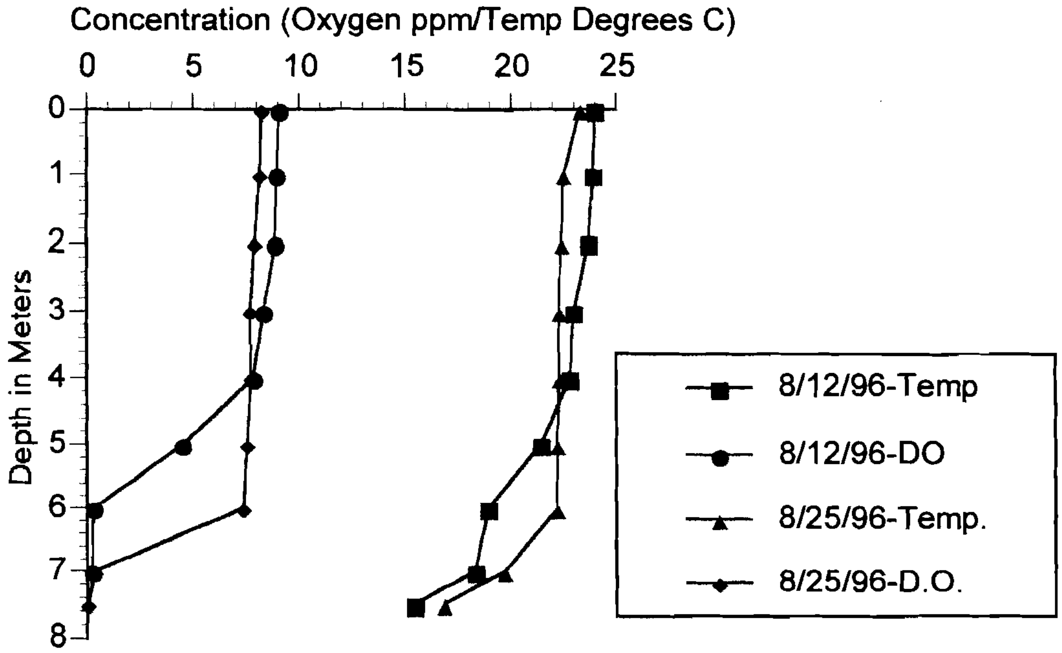


Figure 4. Lake Amnicon Dissolved Oxygen/Temperature profile.

Results from the September sampling indicate a cooling of surface water to below 20°C on 9/20/96. A lack of thermal stratification was apparent with hypolimnetic water exhibiting less than a 2°C difference from the surface water conditions on 9/20/96. These data would indicate a system that has undergone fall overturn (Figure 5).

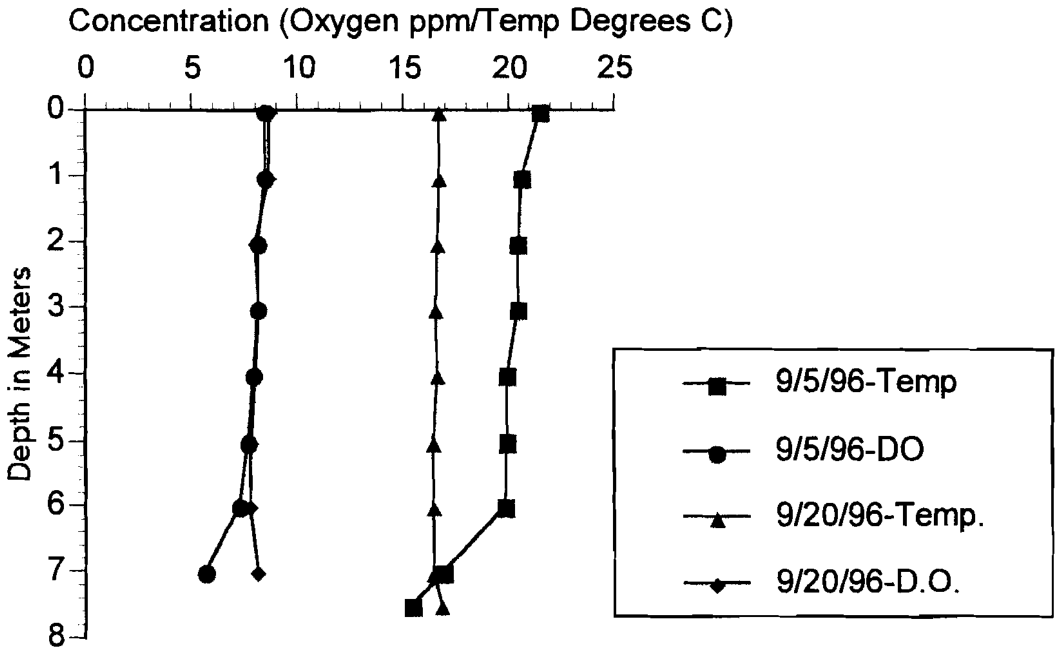


Figure 5. Lake Amnicon Dissolved Oxygen/Temperature profile.

Samples taken in October indicate complete thermocline breakdown with isothermal conditions throughout the month. DO concentrations stayed constant in the hypoliminion to between 5 ppm and 9 ppm for each sampling date(Figure 6a).

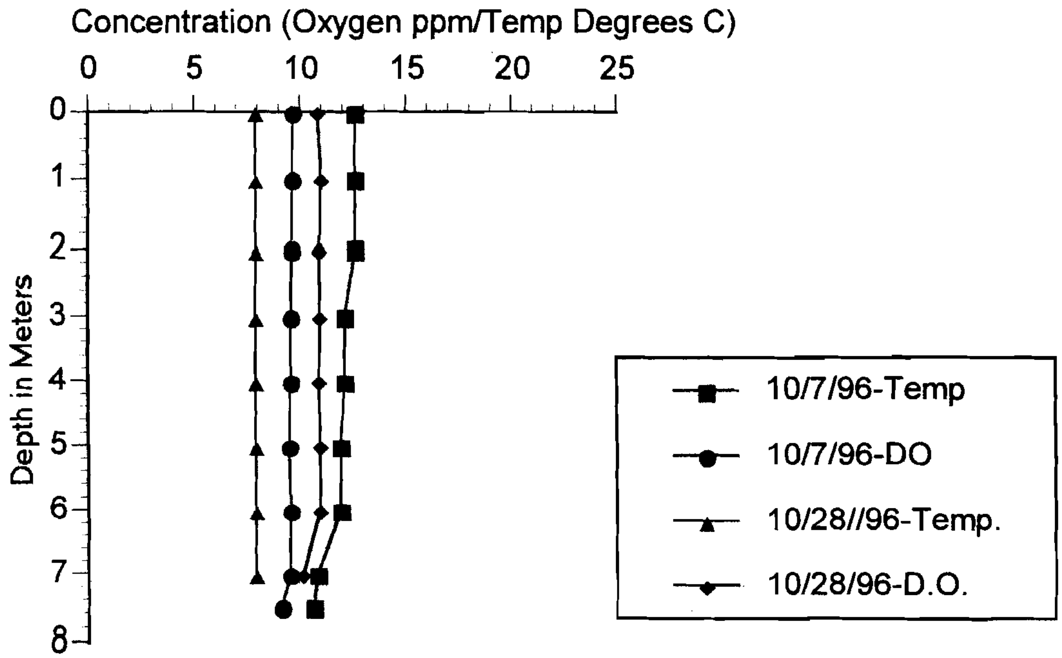


Figure 6a. Lake Amnicon Dissolved Oxygen/Temperature profile.

Profiles form the November sampling indicate rapid water column cooling to 5°C. DO concentrations are at saturation through out the water column (Figure 6b).

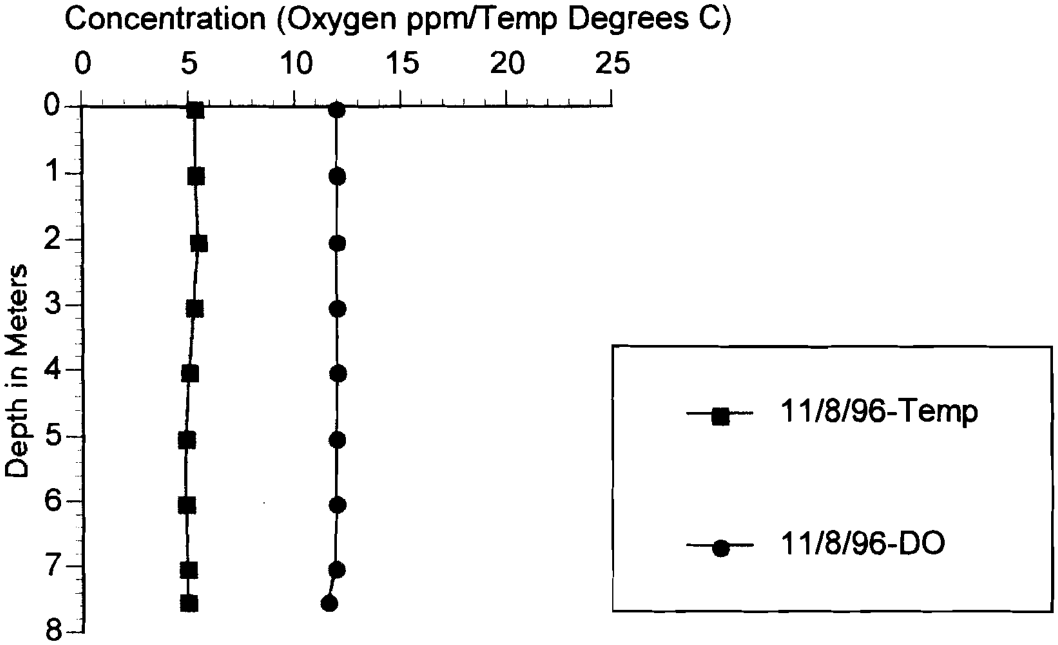


Figure 6b. Lake Amnicon Dissolved Oxygen/Temperature profile.

Results from the December samplings indicate a normal inverse stratification with the surface water (just below the ice) below 4°C, with gradual warming to 4°C at 7 meters. DO was super-saturated on 12/01/96 for the entire water column. Data from 12/29/96 did however indicate significant hypolimnetic demand below 3 meters with a sharp drop in DO from 3-7.5 meters (Figure 7).

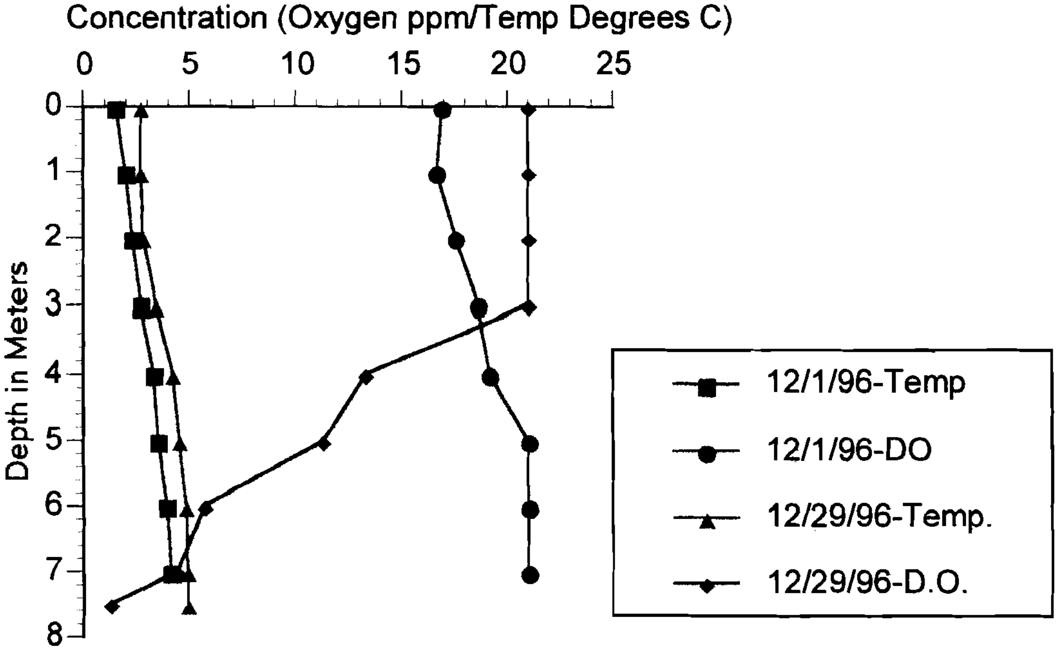


Figure 7. Lake Amnicon Dissolved Oxygen/Temperature profile.

The last sampling of Lake Amnicon at the deep site took place on 1/25/97. Data from this sampling indicate inverse thermal stratification. However of greatest concern is the volume of water containing less than 5 ppm DO. The DO rapidly declines to below 5 ppm at 4 meters and continues to below 2 ppm from 5-7.5 meters. This continues the trend of significant DO demand during the winter months, of concern to the fisheries in the lake (Figure 8).

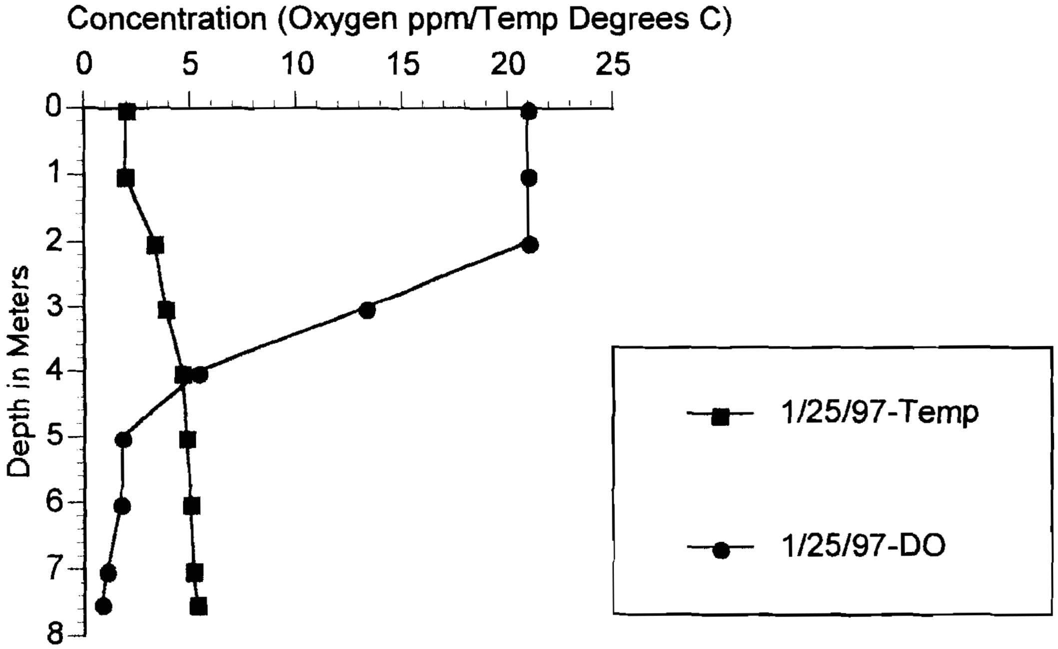


Figure 8. Lake Amnicon Dissolved Oxygen/Temperature profile.

## Lake Dowling Dissolved Oxygen and Temperature Results

The May 19 sampling was performed during spring over-turn as indicated by isothermal conditions with oxygen saturated throughout the water column. DO readings throughout the water column were saturated, measuring more than 11 ppm, (saturation at 11°C is ~11 ppm). DO continued stable with depth (the 3 meter sample indicating nearly 11 ppm). These results indicate a system with weak thermal stratification, susceptible to event-induced re-oxygenation (i.e. wind mixing). The data also suggests that hypolimnetic DO demand is relatively low. (Figure 9).

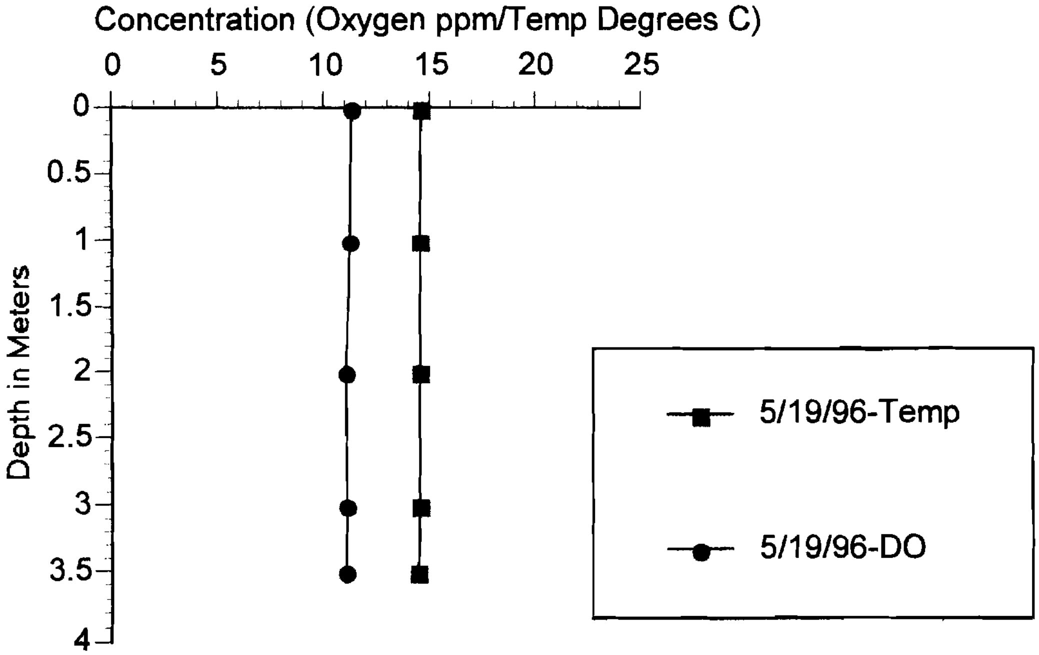


Figure 9. Lake Dowling Dissolved Oxygen/Temperature profile.

June 9th sampling indicated a system with continued surface water warming and weak thermal stratification. DO concentrations were saturated at the surface but indicate a slight rate of depletion below 2 meters to less than 10 ppm from 2-3 meters. June 22nd sampling indicates continued weak thermal stratification and a slight drop in surface water DO saturation. DO levels continued the moderate depletion at 2 meters to below 7 ppm. (Figure 10).

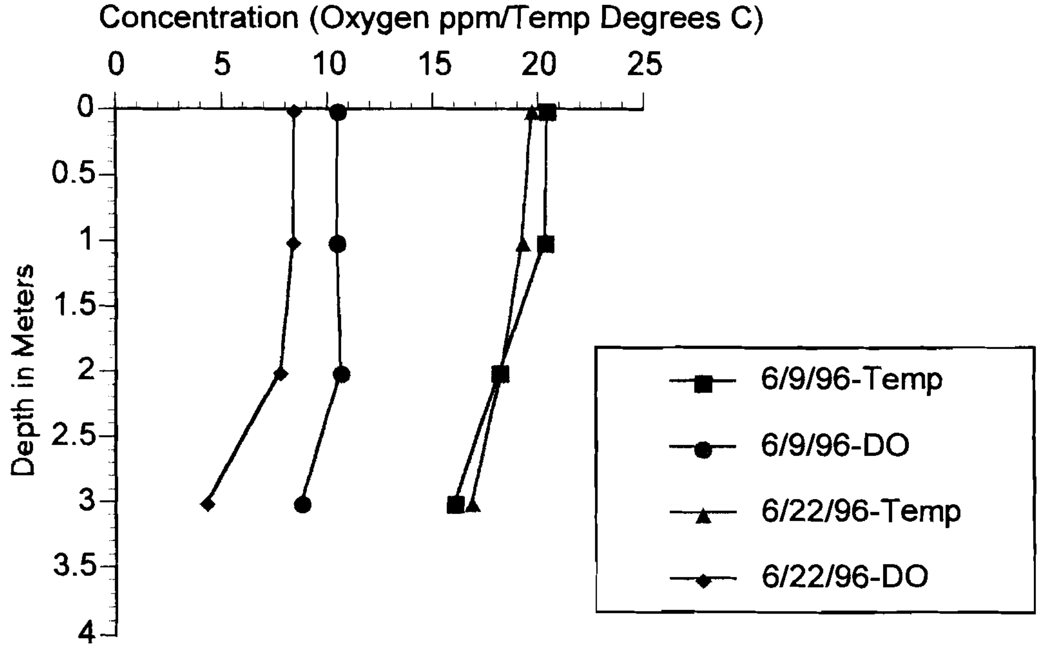


Figure 10. Lake Dowling Dissolved Oxygen/Temperature profile.

July sampling indicates rapid surface water warming to above 20°C on July 14th. The water column did not thermally stratify during this sampling period. DO concentrations remained above 5 ppm for the sample dates (Figure 11).

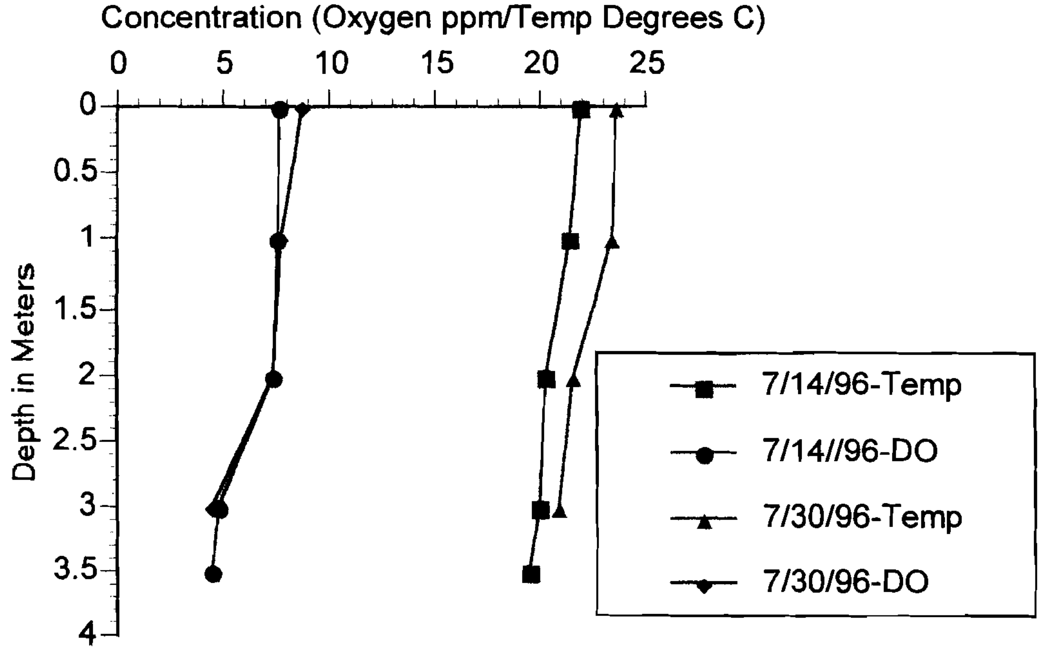


Figure 11. Lake Dowling Dissolved Oxygen/Temperature profile.

August profiles indicate continued surface water warming to above 20°C. The water column did not thermally stratify during this sampling period. DO concentrations remained above 5 ppm for the sample dates (Figure 12).

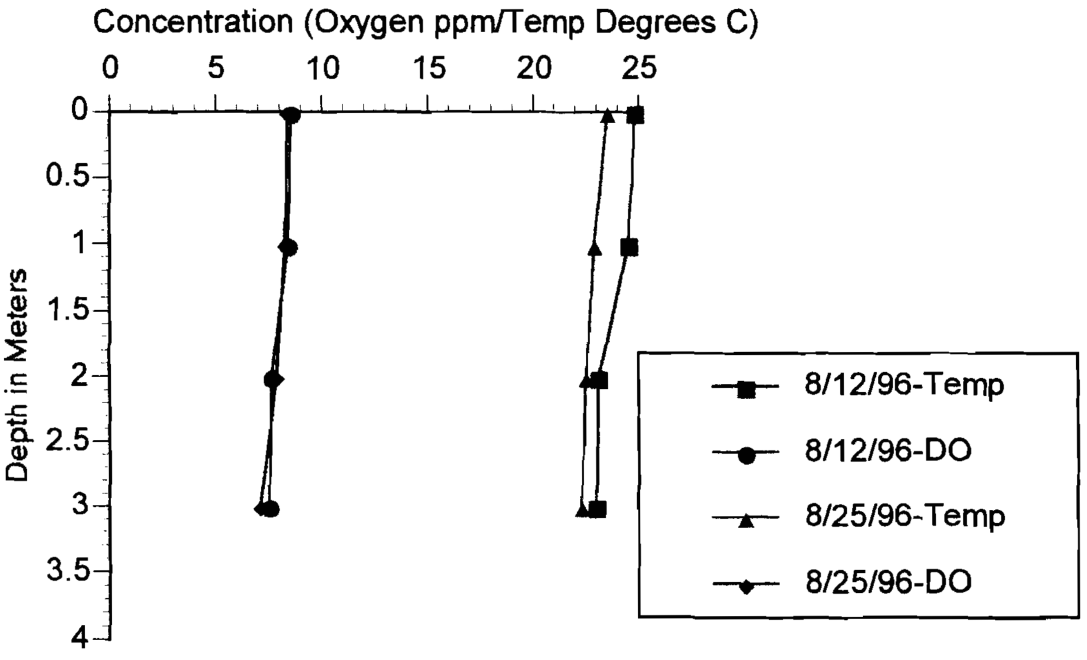


Figure 12. Dissolved Oxygen/Temperature profile.

Results from the September sampling indicate a cooling of surface water to below 20°C on 9/20/96. No thermal stratification was apparent with hypolimnetic water only exhibiting less than 2°C difference from surface water conditions. DO depletion was not evident, indicating complete surface to bottom mixing (Figure 13).

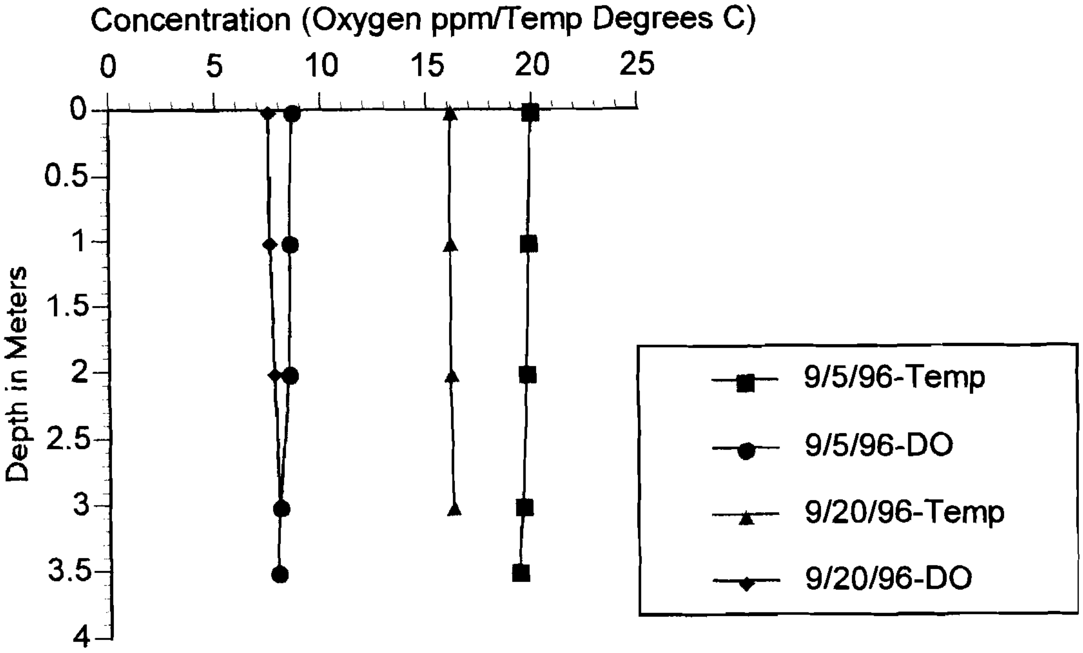


Figure 13. Lake Dowling Dissolved Oxygen/Temperature profile.

Samples taken in October indicate complete thermocline breakdown with isothermal conditions throughout the month. DO concentrations increased throughout the entire water column and resulted in saturated conditions from surface to bottom by 10/28/96 (Figure 14).

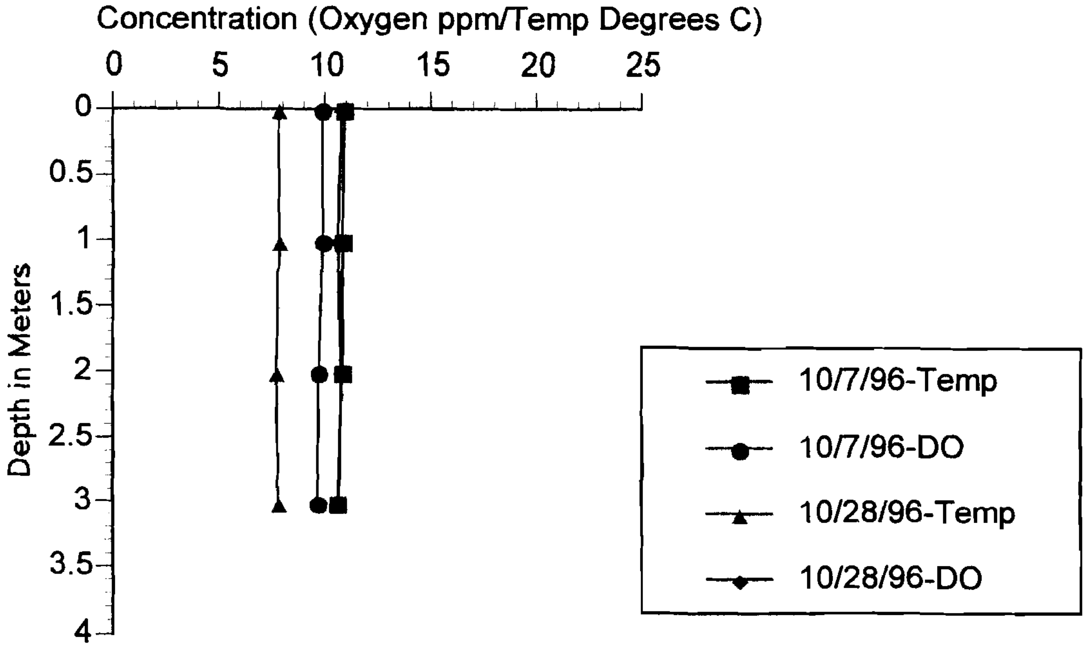


Figure 14. Lake Dowling Dissolved Oxygen/Temperature profile.

November sampling indicates whole column thermal cooling to 6°C. DO was saturated though out the water column during this sampling date (Figure 15).

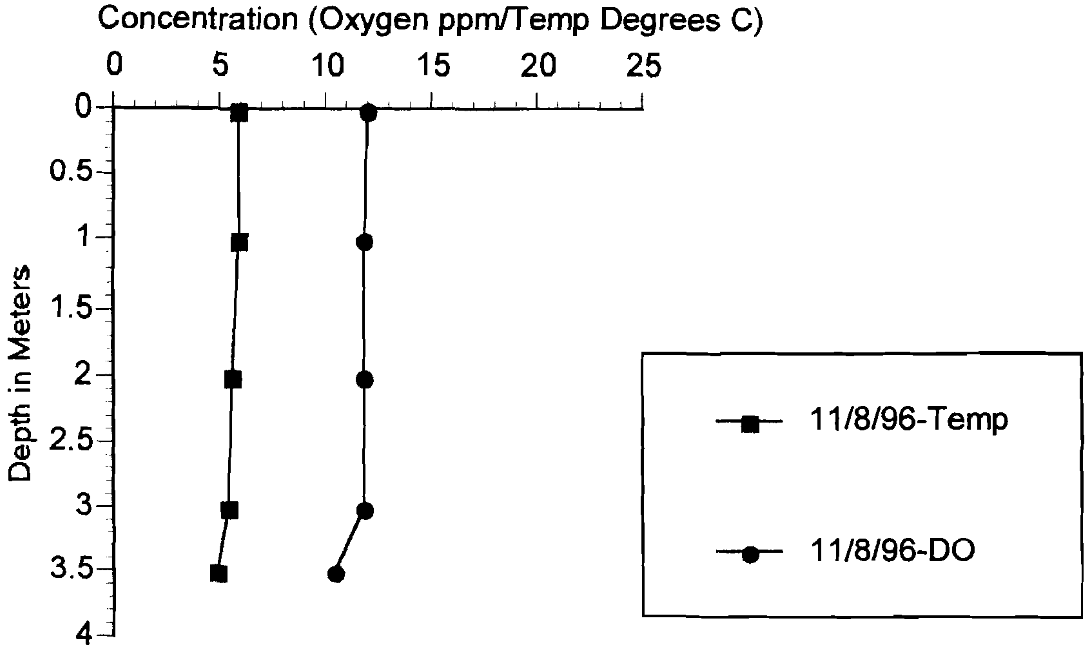


Figure 15. Lake Dowling Temp/D.O Profile

Results from the December samplings indicate a normal inverse thermal stratification with the surface water (just below the ice) below 4°C, with gradual warming to 4°C at 3 meters. DO was below saturation on 12/01/96. DO profiles on 12/29/96 indicate rapid loss in DO for the entire water column. (Figure 16).

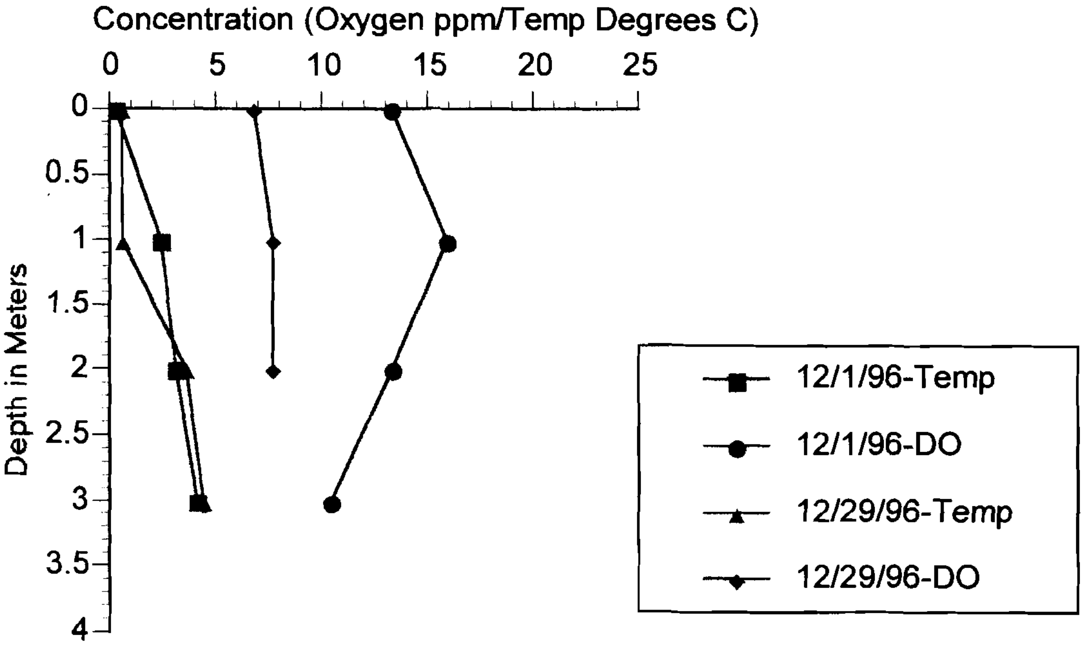


Figure 16. Lake Dowling Dissolved Oxygen/Temperature profile.

The last sampling of Lake Dowling at the deep site took place on 1/25/97. Data from this sampling indicated inverse thermal stratification. DO concentrations were of great concern, dropping to below 5 ppm for the entire water column. (Figure 17).

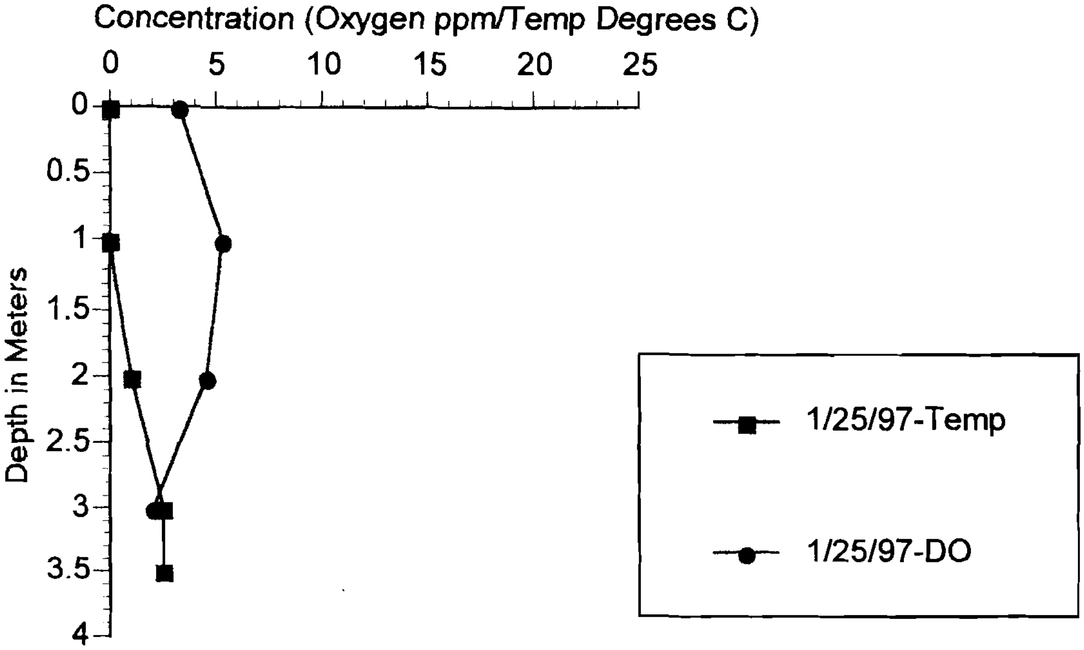


Figure 17. Lake Dowling Dissolved Oxygen/Temperature profile.

## Conclusions: Dissolved Oxygen and Temperature

Results from Lake Amnicon indicate a system undergoing normal weak seasonal stratification and destratification. The lakes may be classified as weakly dimictic in nature because of its susceptibility to wind mixing. Lake Dowling is very susceptible to wind induced mixing, due to the lack of thermal stratification. This weak thermal stratification allows for adequate dissolved oxygen for most of the spring, summer and fall in both lakes. However, when ice cover appears on the lakes, and wind mixing effects are limited, there is a rapid decline in DO concentrations. This is of concern, when a significant portion of the water column is devoid of adequate oxygen to support the lake's fisheries (Appendix 2).

## Evaluated Water Quality Parameters

This section describes the chemical and biological parameters evaluated as part of the 1996-1997 Lake Amnicon/Dowling Monitoring program and special considerations associated with each parameter.

Photo: C.J. Owen and Associates

## *Chlorophyll-a and Phaeophytin-a*

Estimating the concentration of chlorophyll-a (a common green pigment found in algae) remains the most routine method for assessing algal biomass. Algal biomass measurements in turn, provide estimates of the amount of algae present in the lake and are used as an indicator of the productivity of the lake. High average concentrations of chlorophyll-a can be used as indicators of the severity of an algal problem in a lake and are used to appraise the trophic status of a lake.

Phaeophytin-a is a common breakdown product of chlorophyll-a (i.e. dead algae contain phaeophytin-a). Phaeophytin-a should be measured when ever chlorophyll-a is evaluated because phaeophytin interferes with the determination of chlorophyll-a. Phaeophytin-a concentrations can also be used to determine the physiological health of the algae in the system. Low phaeophytin-a:chlorophyll-a ratios indicate healthy algae.

Chlorophyll-a and phaeophytin-a concentrations vary with many physical and biological factors. These factors include, temperature, light, nutrients, lake mixing, algae species, water clarity and presence of zooplankton.

Chlorophyll-*a* concentrations for Lake Amnicon ranged from a high of 8.66 ppb in May to 0.9 ppb in January. Mean summer (June, July and August) chlorophyll-a concentration was 5.95 ppb. This concentration of algal biomass is characteristic of a late mesotrophic to early eutrophic system.

Chlorophyll-*a* concentrations for Lake Dowling ranged form a high of 15.6 ppb in July to .33 ppb in January. Mean summer (June, July and August) chlorophyll-a concentration was 12.01 ppb. This concentration is indicative of a system that is highly eutrophic.

The high chlorophyll-*a* concentrations measured in July in Dowling and August in Amnicon may be due to dominance by the nitrogen fixing blue greens in conditions of low dissolved nitrogen availability. A summary of the chlorophyll-*a* data can be found in Appendix 3. of this report.

## *Phosphorus*

Phosphorus is a fundamental nutrient in the growth of most plants, whether on land or in the water. As such, the amount present in the water greatly affects the amount of algae and other aquatic plants present in a lake. Origins of phosphorus include fertilizers, animal wastes, septic systems, plant decomposition, soil and sediment.

Phosphorus is present in an assortment of forms in the environment. Total phosphorus (TP) provides a measurement of the total concentration of phosphorus present in a system. TP is used in eutrophication models and mass loading calculations to predict productivity and the magnitude of phosphorus inputs. Ortho-phosphorus (OP; also known as soluble reactive phosphorus SRP) is the available form of phosphorus for use by algae and aquatic plants.

Epilimnetic TP for Lake Amnicon ranged from 36 ppb in June to 14 ppb in July, with a summer (June, July and August) mean of 21.7 ppb. This concentration of TP is characteristic of a system that is late mesotrophic to early eutrophic (Figure 18).

Hypolimnetic TP for Lake Amnicon ranged from 32 ppb in December to 18 ppb in June. The concentration of TP in the hypolimnion was relatively constant do to the weak seasonal stratification of the lake the resulting lack of entrainment of TP in the hypolimnion.

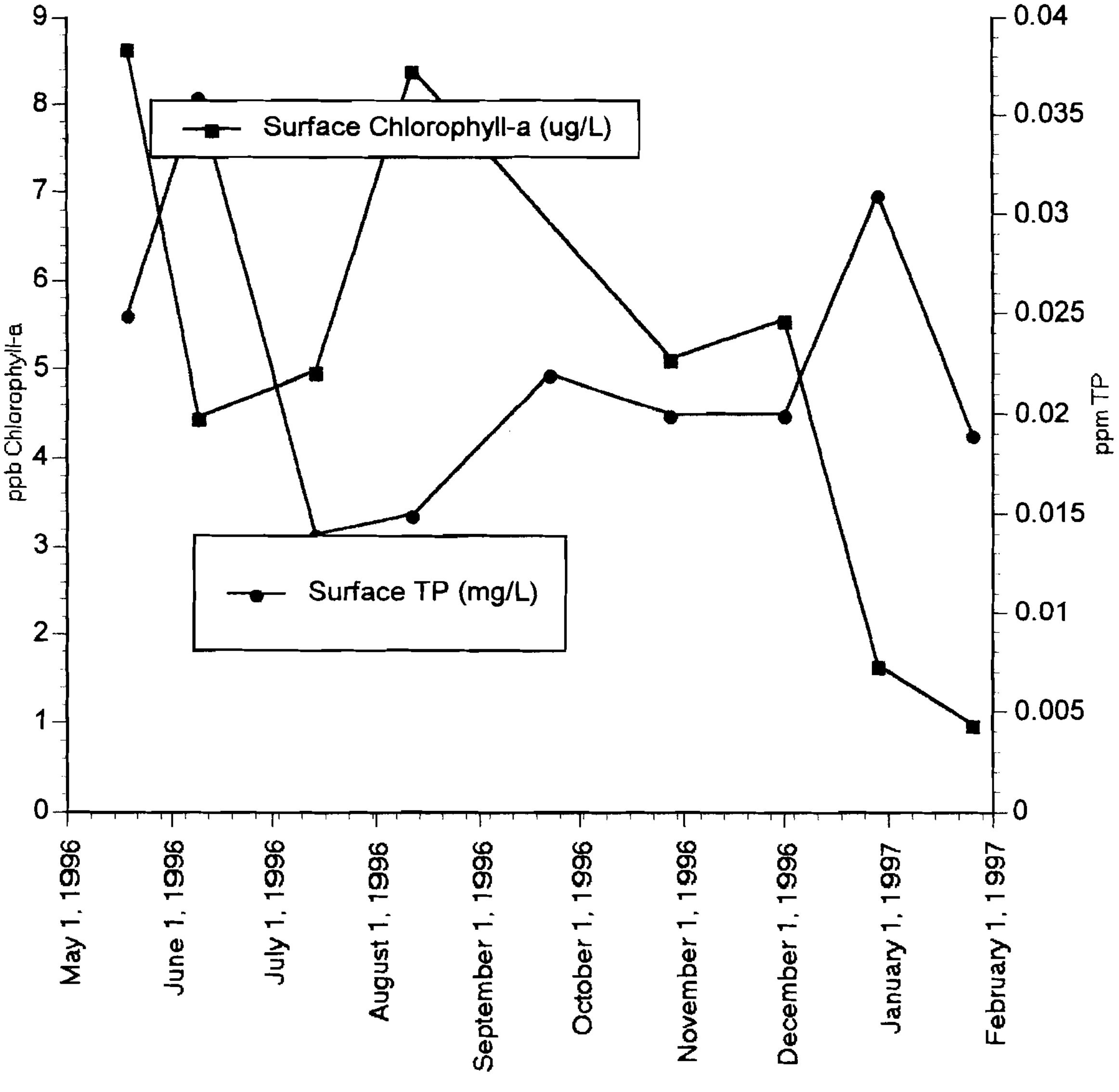


Figure 18. Lake Amnicon TP vs. Chlorophyll-a.

Epilimnetic TP for Dowling ranged from 44 ppb in September to 22 ppb in December, with a summer (June, July and August) mean of 31 ppb. This concentration of TP is characteristic of a system that is mesotrophic to early eutrophic.

Hypolimnetic TP for Dowling ranged from 84 ppb in December to 24 ppb in June. The lack of a buildup of TP in the hypolimnion is due to the weaker stratification of the water column during the summer months at this shallow site, not allowing for the buildup of hypolimnetic TP (Figure 19). A summary of TP data can be found in Appendix 3.

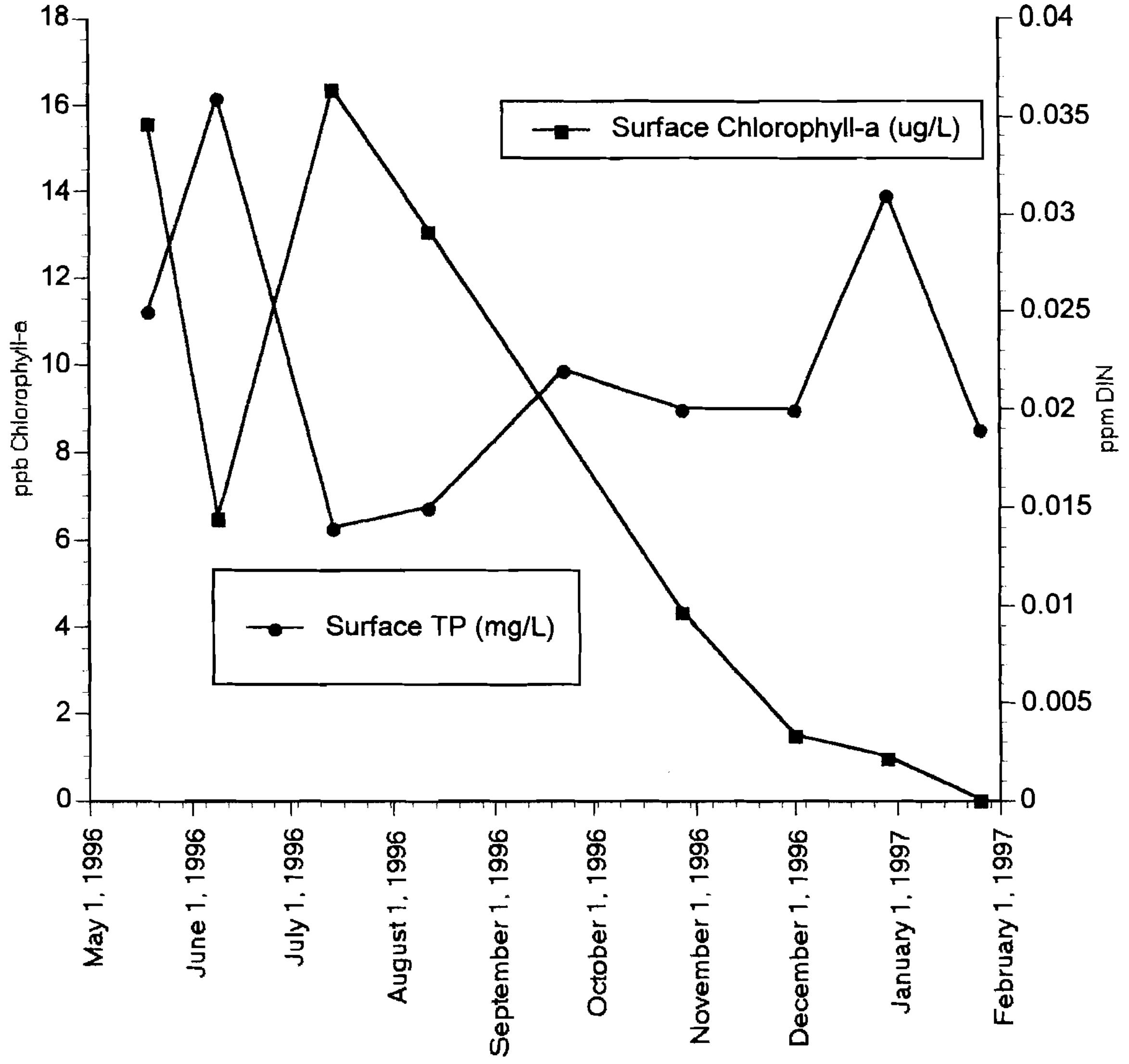


Figure 19. Lake Dowling TP vs. Chlorophyll-a.

OP concentrations for Lake Amnicon and Dowling stayed at or below the detectable limits for most of the year with the exception of Lake August and September when concentrations rose to 32 ppb in Dowling and 14 ppb in Amnicon. This is most likely due to a weak thermal stratification in early August, allowing for sediment release of OP, followed by a subsequent wind mixing event allow for its introduction to the epilimnion. A summary of OP data can be found in Appendix 3 of this report.

## *Nitrogen*

Nitrogen is also a nutrient required for growth of terrestrial and aquatic plants. Specific forms of nitrogen, however, may also be toxic to various organisms. The cycle of nitrogen in the aquatic environment is very complicated in that several forms of nitrogen are present in the environment and undergo transformation as a result of their interactions with various components in the aquatic system.

### *Ammonia-Nitrogen*

Ammonia ($NH_3$-N), an inorganic form of nitrogen, is contained in fertilizers, septic system effluent and animal waste. It is also a product of bacterial decomposition of organic matter. Changes in the concentration of $NH_3$-N are the result of loading, decomposition of organic-N, and oxidation of $NH_3$-N to Nitrate-N.

Epilimnetic ammonia for Lake Amnicon ranged from 117 ppb in December to below detectable limits in May, June, July, August and September.

Hypolimnetic ammonia for Lake Amnicon ranged from 247 ppb in December to below detectable limits in May, June, July, and September. The buildup of ammonia in the hypolimnion in September is due to the strong stratification of the water column during August and September and the resulting release of ammonia from the sediments during anoxic conditions and conversion of nitrate back to ammonia. The availability of these nutrients was not a factor until fall overturn in October resulting in a late season algal bloom.

Epilimnetic ammonia for Lake Dowling ranged from 69 ppb in December to below detectable limits in May, June, July, and August.

Hypolimnetic ammonia for Lake Dowling ranged from 102 ppb in January to below detectable limits in May, June, July, and August.. The erratic nature of the ammonia data indicates a system that is weakly stratified. A summary of ammonia data can be found in Appendix 3.

### *Nitrate+Nitrite-Nitrogen*

Nitrate and Nitrite are inorganic forms of nitrogen present in the environment and can be formed though the oxidation of $NH_3$-N by nitrifying bacteria (nitrification). Nitrate is one of the principal forms of nitrogen used by algae for growth. Of some concern is the toxic effects of nitrate in drinking water, which can cause methemoglobinemia or "blue baby syndrome". Nitrite concentrations are generally small in natural waters and therefore nitrate is usually expressed as Nitrate+Nitrite-N. Nitrate+Nitrite-N concentrations may vary seasonally and with biological activity.

Epilimnetic nitrate for the Lake Amnicon ranged from 164 ppb in January to below detectable limits in June, July, August and September.

Hypolimnetic nitrate for Lake Amnicon ranged from 93 ppb in January to N.D. in June, July, August and September. Lake Amnicon nitrate followed a standard pattern for a strongly stratified lake with an anoxic hypolimnion. Nitrate declined in the hypolimnion during strong stratification and anoxia, with most nitrate converting to ammonia.

Epilimnetic nitrate for the Lake Dowling ranged from 236 ppb in January to below detectable limits in July and August. Hypolimnetic nitrate for Lake Dowling ranged from 224 ppb in January to N.D. in June, July and August. A summary of nitrate data can be found in Appendix 3.

## Dissolved Inorganic Nitrogen

Dissolved inorganic nitrogen (DIN) is defined in this study as nitrate + ammonia. In combination, these two inorganic forms of nitrogen make up the dominate form of nitrogen available for algae.

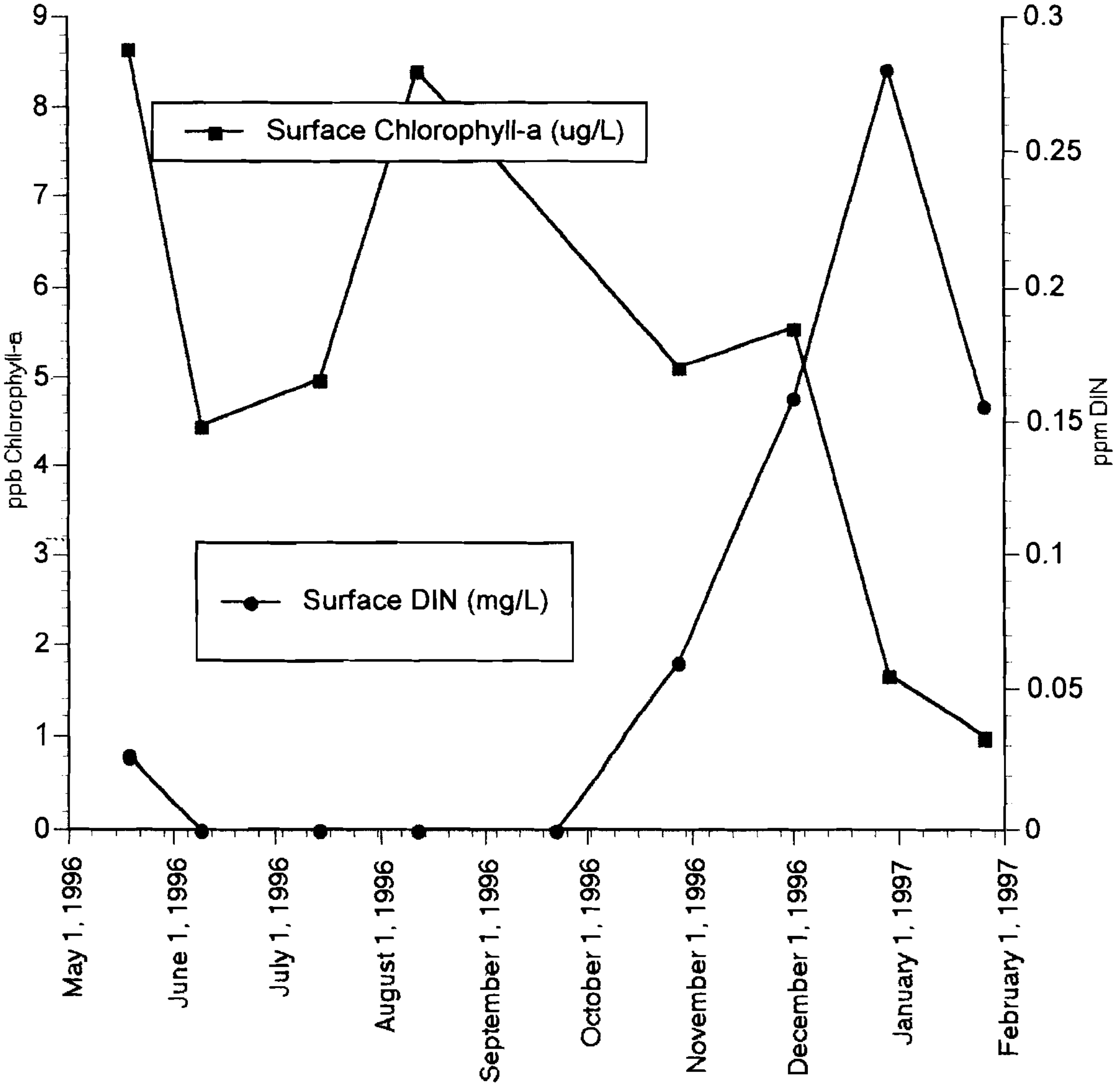


Figure 20. Lake Amnicon DIN vs. Chlorophyll-a.

Lake Amnicon DIN concentrations follow a typical nitrogen limited pattern under conditions of strong thermal stratification and an anoxic hypolimnion, with DIN dropping to below detectable levels by early June and persisting until lake overturn in October (Figure 20). In reaction to the low DIN levels, the blue-green algae capable of fixing atmospheric nitrogen become dominate in September (see phytoplankton section of the report).

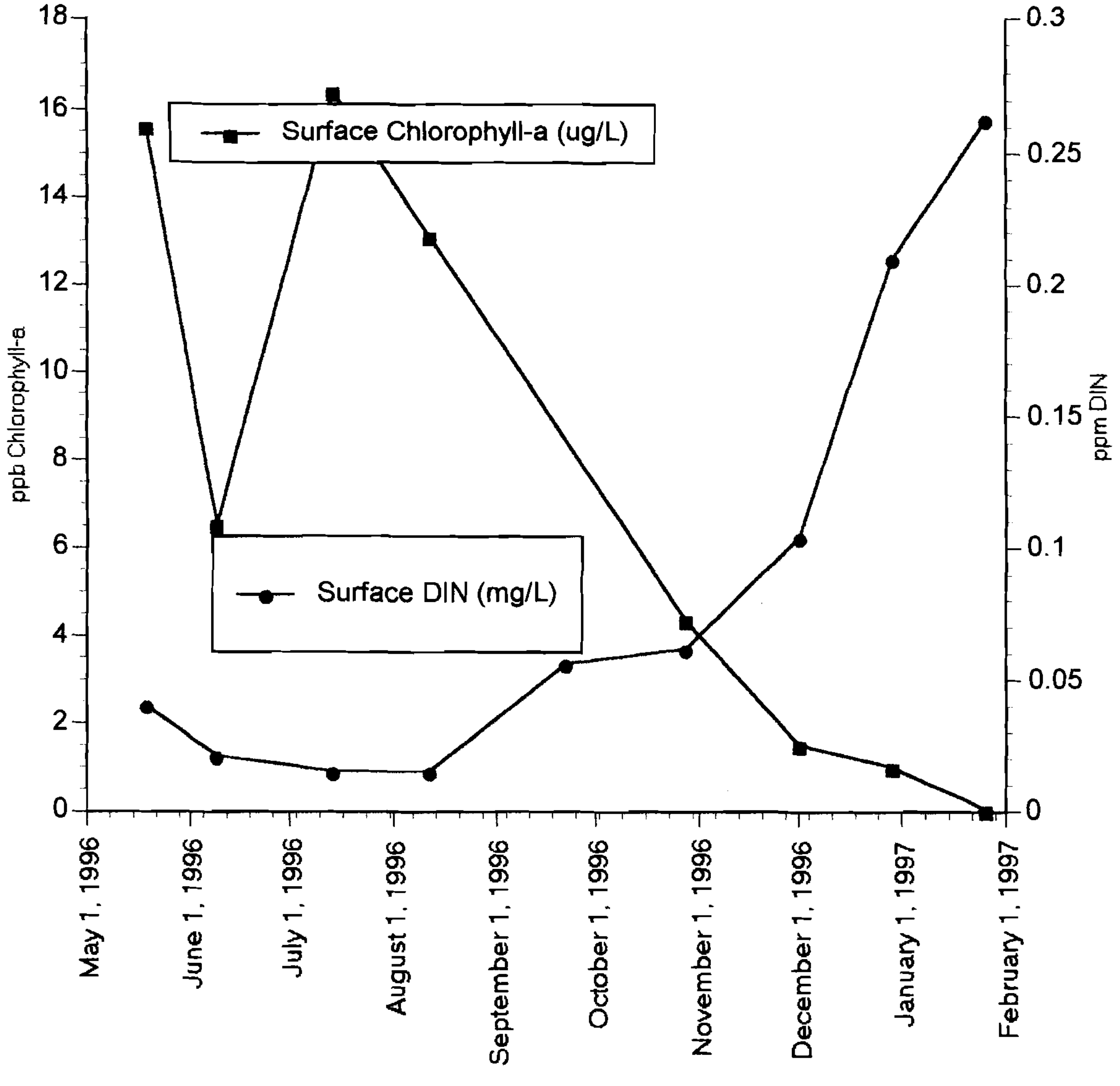


Figure 21. Lake Dowling DIN vs. Chlorophyll-a.

Lake Dowling DIN also indicates a system limited by nitrogen. However, the weak stratification of the site allows for epilimnetic nitrogen to be introduced more readily to the system as indicated by the systematic increase in DIN from October to the end of the sampling season in January (Figure 21).

## *Trophic Status and Trophic State Indices (TSI's)*

Trophic status refers to the rate of organic matter supplied to a lake. This material may be derived in part from direct inputs of vegetative material, sediment (soils), and human/animal wastes, but usually is produced within the lake from the growth of algae and aquatic vegetation. This growth is fueled by nutrients (principally nitrogen and phosphorus) discharged from the watershed, deposited from the atmosphere or released from lake sediments.

Trophic state indices (TSI's) are an endeavor to provide a single quantitative index for the purpose of classifying and ranking lakes, most often from the standpoint of evaluating water quality. In recent years, the Carlson (1977) Index appears to have attained general acceptance in the limnological community as a rational approach to this classification problem. A number of modifications and regional "customizations" of his approach have occurred, but for this evaluation Carlson's index will be used because of its historical use by the Wisconsin-DNR in past evaluations.

Carlson's index resulting in values ranging from 0 to 100 with increasing values indicating more eutrophic conditions. The trophic states for the index are defined by using each doubling of Secchi transparency as the criterion for the division between each state, i.e. each time the transparency doubles from some base value, a decrease in TSI-S (trophic state indices for Secchi depth) of ten occurs. The relation of Secchi depth to total phosphorus is a simple inverse function, so a doubling of total phosphorus causes the TSI-P (trophic state indices for phosphorus) to increase by 10 units. Both TSI-P and TSI-S are related to chlorophyll-a̲ concentration. The resulting relationship results in the third TSI, TSI-C (trophic state indices for chlorophyll). The indices are based on the following three expressions:

$$\text{TSIP} = 4.15 + (14.42 * \ln\text{TP}), \text{ in } \mu\text{g/L}.$$

$$\text{TSIC} = 30.6 + (9.81 * \ln \text{Chlorophyll-a}), \text{ in } \mu\text{g/L}.$$

$$\text{TSIS} = 60.0 - (14.41 * \ln \text{Secchi Depth}), \text{ in meters}.$$

The following "rules" were applied when using TSI's:

1) If one index value is based on numerous measurements, while the other is based on a single measurement, then the former is used as a better indicator.

2) If there is only a single measure for each or an equal number of measures, the TSI-P value was favored.

3) TSI-S and TSI-C based on a single measure were viewed with caution.

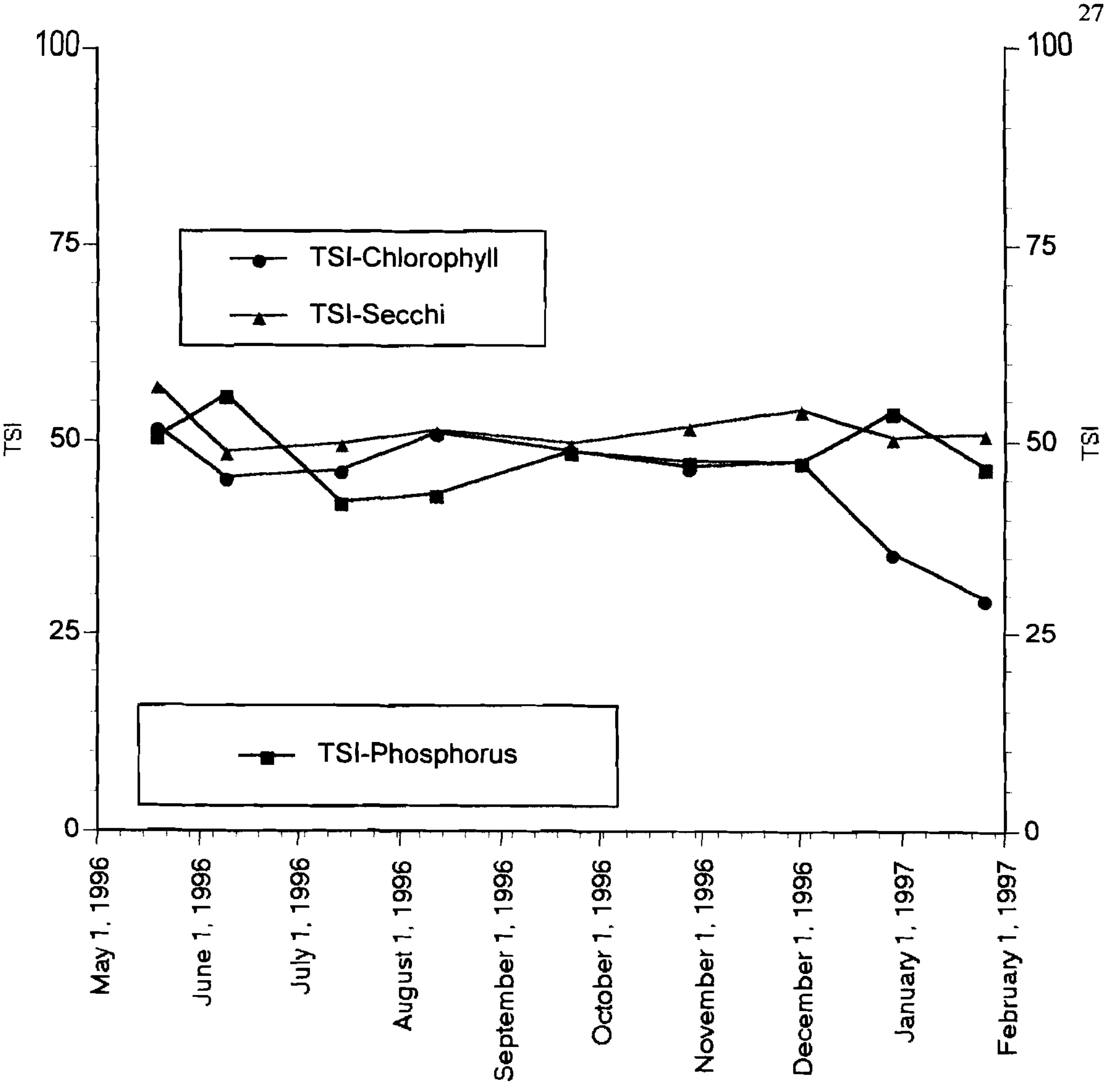


Figure 22. Lake Amnicon TSI summary.

TSI's of < 30 are classical oligotrophic lakes with clear water and oxygen in the hypolimnion though out the year. TSI's of 30-40 are characteristic of deeper lakes which still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion in the summer. TSI's of 40-50 are characteristic of lakes that are moderately cleat, but increasing the probability of anoxia in the hypolimnion during summer. TSI's of 50-60 are on the lower boundary of classical eutophy with decreasing transparency, anoxic hypolimnia during the summer and macrophyte problems are evident. TSI's of 60-70 are dominated by blue-green algae, having algal scum problems and extensive macrophyte problems. TSI's of 70-80 have heavy algal blooms possible though out the summer, have dense macrophyte beds and limitations on light penetration and is classified as hypereutrophic. Any TSI over 80 will have algal scums, summer fish kills and few macrophytes.

The summer mean TSI for Lake Amnicon is 48. This TSI indicates a system that is late mesotrophic or early eutrophic in nature with decreased transparency and a high probability of an anoxic hypolimnia during summer and a potential macrophyte problem (Figure 22).

The summer mean TSI for Lake Dowling is 55. This TSI indicates a system that is mid-eutophic in nature, also with decreased transparency . However, because of the shallow nature of the lake, and in turn an increased susceptibility to wind mixing, an anoxic hypolimnia during summer was not detected. The oxygen did however decrease to levels of concern during winter when decomposition processes drove DO levels to extremely low levels. The stained nature of the water in Dowling has limited the extent of the macrophyte problem when contrasted to Amnicon (Figure 23).

## ***Secchi Depth Related to TSI***

Secchi depth, or transparency, provides a measure of the depth of light penetration. The depth of penetration is significant because it controls the depth to which photosynthesis can occur. Photosynthesis in turn, controls the amount of oxygen that can be produced and made available to other organisms. Secchi measurements may seem simple or "low-tech" but they provide very practical information for the evaluation of the trophic status of a lake ( the greater the Secchi depth, generally the more oligotrophic the status). Factors affecting Secchi depth may be seasonal or spatial in nature, varying due to lake mixing, storm runoff, lake morphometry and the amount of algae and color associated with the lake. A summary of Secchi depths can be found in Appendix 2.

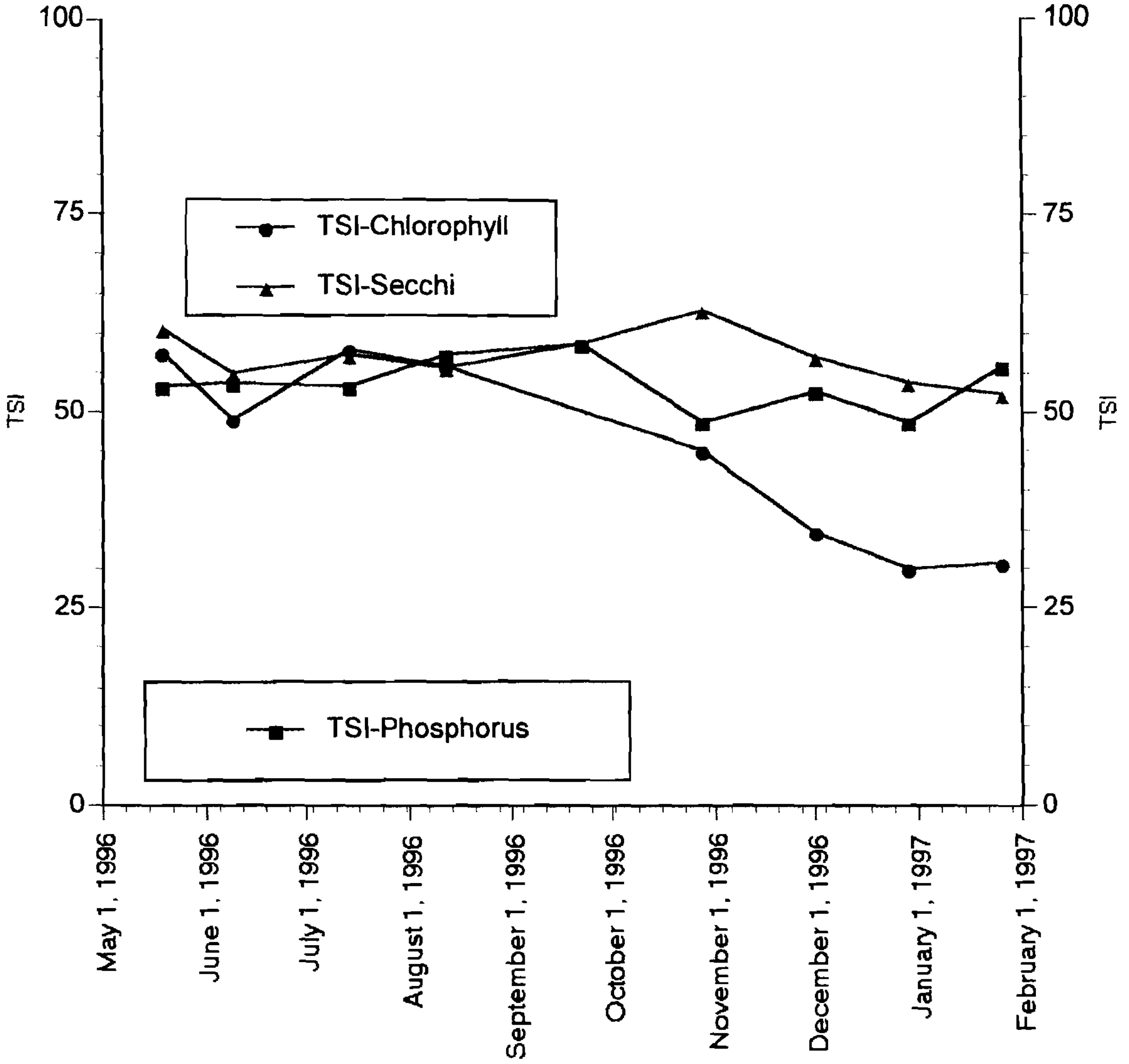


Figure 23. Lake Dowling TSI summary.

## ***Nutrient Ratio Indices***

A common management strategy for slowing the eutrophication process has been to limit the inputs of growth-inducing nutrients. The nutrients most likely to limit algal growth include phosphorus and nitrogen. In an effort to make an estimate of which nutrient is limiting in a system and in doing so, concentrate control efforts on that nutrient, the following nutrient indices have been used:

1) TN:TP
2) DIN:SRP
3) DIN:TP

Various field studies have suggested that TN:TP ratios greater that 15:1 to 21:1 indicate P deficient systems. When using the DIN:SRP indices, ratios greater than 20:1 indicate P limited systems while ratios below 3:1 indicate N limited systems. The third index (DIN:TP) indicates that ratios greater than 4.0 suggest P limitation, while ratios less than 1.3 where associated with N limited systems. Only the most sensitive indicators (DIN:TP and DIN:SRP) were used in this study.

The SRP portion of the ratio indicators does skew the data because this is the most available form of the nutrients in the ratios and is quickly assimilated, bringing into question its usefulness as a ratio indicator. For both lakes DIN/SRP ratio results indicate "P" limitation. However, the most accurate indicator (DIN/TP) indicates "N" limitation. The results suggest the systems are co-limited by nitrogen and phosphorus. This indicates that the system will react (i.e. producing algal blooms) to any additions of external P and N. Ratios can be found in Appendix 3.

Photo: C.J. Owen and Associates.

## ***Phytoplankton***

Phytoplankton measurements are valuable indicators of water quality, because the species and abundance present have been correlated to distinct water quality conditions, with some species thriving in eutrophic systems and others showing sensitivity to various pollutants. The presence of blue-green algae, their relative abundance and bloom frequency, is a primary qualitative indicator of degrading trophic status.

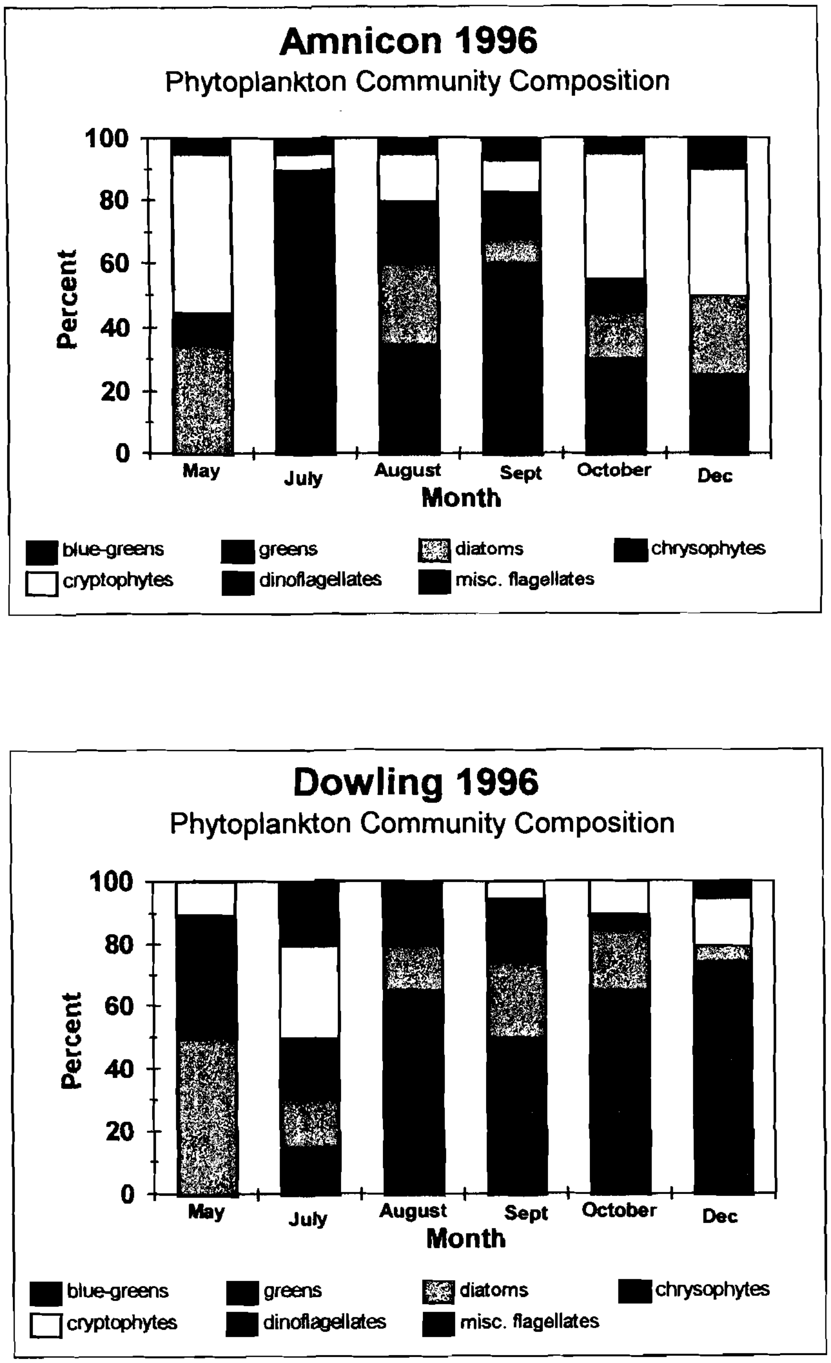


Figure 24. Lake Amnicon/Dowling phytoplankton summary.

Lake Amnicon phytoplankton data indicates a system that is initially "normal" in its species composition but is soon dominated by blue-greens and later blue-greens with heterocysts (indicating system sensitivity to DIN inputs). The species diversity and abundance is characteristic of a system that is late mesotrophic to early eutrophic (Figure 24).

Dowling phytoplankton data indicates a system with an early presence and subsequent dominance by blue-green algae. This is characteristic of a eutrophic system (Figure 24).

## ***Major Ions (Anions-Cations)***

A characterization of major anions (chloride and sulfate) and cations (calcium, magnesium, sodium and potassium) provide important information regarding the linkage of the lake water and the soils in the watershed. These data are useful for estimating potential fishery production, groundwater seepage, road salt input, septic tank leakage and system sensitivity to heavy metal input.

Chloride was stable at both sites during the season. This data is useful as a background marker for nearshore groundwater testing where chloride may be used as a tracer for septic leachate.

Calcium, magnesium, sodium and potassium were also normal for a dimictic lake. These data are also useful as a background by which future studies will be based.

Manganese fluctuated somewhat during the year. Some fluctuation is expected during the year due to sediment release of manganese however the large variability in the data set is greater than expected. The reason for this is yet unknown.

## Groundwater Analysis

As stated in the introduction, when using the data generated by this study it should be recognized that the focus of the sampling design is on protection of the health of the lake (i.e. the processes that effect how rapidly the lake ages-eutrophication-and the "usability" of the water resource for humans as well as animals). However, some of the data gathered may be taken into consideration when controlling possible impacts on the health and well being of the people utilizing the lakes.

Further, as stated in the introduction, the current project focus on developing long term management activities to help maintain the health of the lake. In an effort to address this focus, analysis of water quality perimeters have taken the whole lake as a potentially impacted resource, influenced by the entire community within the lake(s) watershed. Results from the inlake studies of 1994, 1995 and this report should be characterized as an over all community problem to be addressed and does not indicate individual(s) responsibilities for a given source of impact from a geographical area. This holds true for the groundwater analysis, in that only a small portion of the groundwater input was sampled and analyzed. Resources are not available to assess each individual for quantifiable impacts on the water quality of the lakes, rather the data suggests possible avenues by which the community as a whole my be impacting the water resource.

In order to determine flow direction and quality, 36 observation wells were installed in the Amnicon-Dowling area in 1979. These wells were clustered in groups of two or three (a shallow lowland well, a shallow upland well and at six sites a deep lowland well) at 15 locations around the lake as part of the 1978-1979 Lake Amnicon and Dowling study (WI-DNR, 1980). Permeability was quite varied due to the unsorted glacial deposits. The maximum permeability was 117 gallon/square foot/day and was measured at the well site "J-lowland", located in the populated north shore of Amnicon Lake. At the time standard practice was to filter samples in the lab just prior to analysis (WI-DNR, 1980). This practice resulted in loss of soluble phosphorus (greater than 80%) due to reactions with iron and manganese under oxygenated conditions. On May 27-28, 1996 C.J Owen and Associates attempted to locate and sample the "lowland" wells at eight sites on Amnicon Lake and six on Dowling Lake using procedures developed to minimize unwanted chemical reactions. Of the 14 sites on the two lakes only 3 wells were located, 2 on Lake Amnicon (sites SM-OL and SM-2X) and one on Dowling (SM-10Y) (see Map 3-4 Appendix 1). None of the 3 wells were viable with regard to producing adequate aliquots of water for sampling purposes. It was determined at this time to add a similar quantity of seepage meters to both lakes to complete the study.

Twenty-eight seepage meters with a modified design of Lee (1972) were constructed and deployed in Lake Amnicon and Lake Dowling on June 28, 1996 (Appendix 1;Maps 3-4). Seepage meters were sampled on July 14, and September 22, 1996 relying on adequate flow rates to fill the volume necessary to perform analysis on the samples. The duration of deployment for the first sampling was seven days. The second sampling was taken after 26 days. Flow rates decreased significantly over the season, only allowing for two samplings during the field season. A below the ice sampling was taken on February 2, 1997 at the locations of the seepage meters but not from them. Results of this sampling are given in Appendix 4. For our purposes will not be considered as representative of groundwater. Seepage meters were constructed of 0.35 meter diameter plastic "bowl" catch basins. A 20 cm. x 2 cm. polyvinyl chloride collection tube was inserted through the top of the meters using water proof fittings. Meters were slowly inserted into the lake sediment in 0.5-1.0 meters of water. Depth of sediment penetration did not exceed 10 cm. Meters were installed at a slight angle to promote flow towards the collection system and to allow gas released from the sediments to escape through the unsealed collection tube. Meters were left un-bagged for a minimum of seven days prior to securing the collection bags to the collection tube. This allowed for complete flushing of lake water form the collection system and to allow benthic organisms to escape.

Thick plastic collection bags were secured to the system using plastic quick release clamps. Care was taken to insure that the bags had adequate expansion, with low resistance to flow. Bags were sampled by twisting the bag above the clamp to limit the exposure of the sample to ambient air and lake water. Samples were then transferred into pre-preserved sampling bottles, chilled and shipped via overnight UPS to the Wisconsin Department of Health State Laboratory of Hygiene for analysis.

Chemical parameters examined from the seepage meters include all or some of the following depending on the amount of water collected:

Chloride (Table 2.)
Iron (Table 3.)
Ammonium (Table 4.)
Nitrate (Table 5.)
Total Phosphorus (Table 6.)
Orthophosphate (Table 7.)
Conductivity (Table 1.)
Bacteria-Optical Brighteners -F. Coliform, F. Strep, and E. Coli (Table 8.)

Analysis is based on a comparison of groundwater entering the seepage meters with ambient deep hole chemical parameters from the nearest sampling date as well as a comparison to "enforcement standards" and "preventative action limits (PAL)" outlined in Wisconsin Groundwater Standards (see Appendix 6) where applicable.

Appendix 4. represent the chemical data derived from the seepage meter study for 1996. Areas of concern are highlighted if they exceed ambient conditions by more than 10%. Ambient conditions are described as the chemical parameters from the deep hole site on each lake for the nearest date. If the sites exceed "enforcement standards" or "PAL" they are denoted with an X in the appropriate column. Sites can be referenced for location with maps located in Appendix 4.

*Conductivity and Ion(s) present in Seepage Meters*

The chemistry of $Fe_{sol}$ is very complex in that the solubility of iron is subject to change depending upon whether oxygen is present in the water. Iron exists in solution in either the ferrous ($Fe^{++}$) or ferric ($Fe^{+++}$) state. Ferrous ions tend to be more soluble than ferric ions in water (Wetzel, 1975). Under anaerobic conditions the predominant form of iron would be the reduced form ($Fe^{++}$) which is more soluble in water. These conversions in iron can be used to identify reducing conditions in septic systems by identifying intervals where iron ($Fe^{++}$) is present in monitoring wells and seepage meters by correlating increases in $Fe_{sol}$ with loss in $NO_3$ and persistence of $NH_4$ in groundwater samples.

Non-natural or anthropogenic inputs of $Cl^-$ may significantly increase the $Cl^-$ concentration in natural waters. De-icing salt used on road may cause significant levels of man-derived $Cl^-$. In the case of Amnicon and Dowling Lakes, very little salt is used for de-icing. Sewage waste water is another potential man-derived source of $Cl^-$. Domestic wastewater has a typical $Cl^-$ concentration of approximately 50 mg/liter (Hanes et al., 1970). Exfiltration of $Cl^-$ from leach fields will leave elevated levels in nearshore wells as well as elevated levels in sediment interstitial water and the lake. Other dissolved ions from septic leachate can be measured as conductivity. Elevated conductance measurements in groundwater can be related to groundwater contamination as it flows though old and/or failing leach fields and will show up as elevated levels in wells and seepage meters.

**Amnicon Seepage Meter Conductivity Analysis 1996**

**Table 1.**

| SITE | 7/14 Level Uhmos | 7/14 Ambient Uhmos | 9/22 Level Uhmos | 9/20 Ambient Uhmos | Protective Action Limit | Enforcement Standard |
|---|---|---|---|---|---|---|
| SM-OL | 50 | 50 | 50 | 52 | NA | NA |
| SM-2X | 319 | 50 | 58 | 52 | | |
| SM-3X | | | 71 | 52 | | |
| SM-4X | 158 | 50 | | | | |
| SM-5X | 65 | 50 | 80 | 52 | | |
| SM-6X | | | 65 | 52 | | |
| SM-7X | | | | | | |
| SM-8X | | | 52 | 52 | | |
| SM-9X | 162 | 50 | 90 | 52 | | |
| SM-10X | 112 | 50 | 51 | 52 | | |
| SM-11X | | | 51 | 52 | | |
| SM-12X | | | 50 | 52 | | |

## Dowling Seepage Meter Conductivity Analysis 1996

| SITE | 7/14 Level Uhmos | 7/14 Ambient Uhmos | 9/22 Level Uhmos | 9/20 Ambient Uhmos | Protective Action Limit | Enforcement Standard |
|---|---|---|---|---|---|---|
| SM-1Y | | | 70 | 41 | NA | NA |
| SM-2Y | | | 30 | 41 | | |
| SM-3Y | | | 50 | 41 | | |
| SM-4Y | 45 | 50 | 50 | 41 | | |
| SM-5Y | | | 30 | 41 | | |
| SM-6Y | | | 40 | 41 | | |
| SM-7Y | 80 | 50 | 40 | 41 | | |
| SM-8Y | | | 50 | 41 | | |
| SM-9Y | 35 | 50 | 39 | 41 | | |
| SM-10Y | 85 | 50 | 40 | 41 | | |
| SM-11Y | | | | | | |

## Amnicon Seepage Meter Chloride Analysis 1996

**Table 2.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 10/28 Ambient Mg/L | Protective Action Limit Mg/L | Enforcement Standard Mg/L |
|---|---|---|---|---|---|---|
| SM-OL | 3.9 | 2.5 | 2.3 | 2.4 | 125 | 250 |
| SM-2X | 18 | 2.5 | 2.7 | 2.4 | | |
| SM-3X | | | 2.5 | 2.4 | | |
| SM-4X | 3.8 | 2.5 | | | | |
| SM-5X | 3.8 | 2.5 | 3.3 | 2.4 | | |
| SM-6X | | | 1.7 | 2.4 | | |
| SM-7X | | | | | | |
| SM-8X | | | 2.3 | 2.4 | | |
| SM-9X | 4.9 | 2.5 | 3.4 | 2.4 | | |
| SM-10X | 3.1 | 2.5 | 2.3 | 2.4 | | |
| SM-11X | | | | | | |
| SM-12X | | | 2.4 | 2.4 | | |

## Dowling Seepage Meter Chloride Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 10/28 Ambient Mg/L | Protective Action Limit Mg/L | Enforcement Standard Mg/L |
|---|---|---|---|---|---|---|
| SM-1Y | | | 1 | 1 | 125 | 250 |
| SM-2Y | | | | | | |
| SM-3Y | | | 1.5 | 1 | | |
| SM-4Y | 2.2 | 1.3 | .9 | 1 | | |
| SM-5Y | | | .9 | 1 | | |
| SM-6Y | | | 1 | 1 | | |
| SM-7Y | 1.9 | 1.3 | | | | |
| SM-8Y | | | 1.3 | 1 | | |
| SM-9Y | 1.5 | 1.3 | ND | 1 | | |
| SM-10Y | 1.8 | 1.3 | | | | |
| SM-11Y | | | 1.3 | 1 | | |

## Amnicon Seepage Meter Iron Analysis 1996

**Table 3.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 10/28 Ambient Mg/L | Protective Action Limit Mg/L .15 | Enforcement Standard Mg/L 3 |
|---|---|---|---|---|---|---|
| SM-OL | | | .17 | .1 | X | |
| SM-2X | .16 | .2 | .09 | .1 | | |
| SM-3X | | | 2.1 | .1 | X | |
| SM-4X | 1.6 | .2 | | | | |
| SM-5X | | | .65 | .1 | X | |
| SM-6X | | | .25 | .1 | X | |
| SM-7X | | | | | | |
| SM-8X | | | .13 | .1 | | |
| SM-9X | | | .15 | .1 | | |
| SM-10X | .29 | .2 | .14 | .1 | | |
| SM-11X | | | | | | |
| SM-12X | | | .17 | .1 | X | |

## Dowling Seepage Meter Iron Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 10/28 Ambient Mg/L | Protective Action Limit 15 Mg/L | Enforcement Standard 3 Mg/L |
|---|---|---|---|---|---|---|
| SM-1Y | | | 1.4 | .61 | X | |
| SM-2Y | | | | | | |
| SM-3Y | | | .38 | .61 | X | |
| SM-4Y | | | .59 | .61 | X | |
| SM-5Y | | | 1.3 | .61 | X | |
| SM-6Y | | | .71 | .61 | X | |
| SM-7Y | | | .71 | .61 | X | |
| SM-8Y | | | .84 | .61 | X | |
| SM-9Y | | | .93 | .61 | X | |
| SM-10Y | | | | | | |
| SM-11Y | | | .67 | .61 | X | |

*Groundwater Nutrient Data*

Forms of nitrogen present in septic tank effluent include ammonia, ammonium, organic nitrogen, nitrate and nitrite. Only a small part, perhaps 10%, of the total nitrogen in raw wastewater is removed via sludge that accumulates in the bottom of septic tanks. Several other mechanisms exist in the soil for transformation, retention and movement of nitrogen. The mechanisms include denitrification, absorption, plant uptake and volatilization. Some of the nitrogen in effluent may be removed by one or more of these mechanisms before the effluent reaches groundwater, but half or more of the nitrogen is likely to travel with effluent to the groundwater.

Anaerobic digestion in conventional septic tanks converts most of the phosphorus into soluble (algal available) orthophosphate. In contrast to the highly mobile nitrogenous components, most phosphate reacts vigorously with soils. Phosphate ions are removed by several mechanisms, including absorption, precipitation, plant uptake and biological immobilization. Phosphorus transport through soils is more likely to occur, however, in coarse-textured, noncalcareous soils that are low in organic matter or where the depth to the water table is shallow. Where these conditions exist and/or where septic systems are in close proximity to surface waters, phosphorus transport to these waters is likely.

Conditions identified by the 1993 Septic and Water Quality Survey indicate increased loading to septic systems (conversion from seasonal to primary residents), the primary use of septic-drainfield type systems with inappropriate soils (U.S. Department of Agriculture-Soil Survey), aging systems with greater than 38% of the systems $20^{+}$ years old, close proximity of systems to the lake with a high occurrence of saturated soils and the majority of properties below the 10 foot shoreline couture. These conditions are ideal for unwanted transport of nutrients from groundwater to surface waters.

Data from the 1994, 1995 and 1996 studies indicate systems co-limited by phosphorus and nitrogen (early dominance of hetrocystic forms of blue-green algae); of concern is the transport of these nutrients from the groundwater to these N&P limited systems, thereby stimulating unwanted algal growth.

Photo: C.J. Owen and Associates

## Amnicon Seepage Meter Ammonia Analysis 1996

**Table 4.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | Protective Action Limit Mg/L | Enforcement Standard Mg/L |
|---|---|---|---|---|---|---|
| SM-OL | .367 | ND | ND | ND | NA | NA |
| SM-2X | 2.21 | ND | ND | ND | | |
| SM-3X | | | .906 | ND | | |
| SM-4X | 1.97 | ND | | | | |
| SM-5X | .863 | ND | 1.02 | ND | | |
| SM-6X | | | ND | ND | | |
| SM-7X | | | | | | |
| SM-8X | | | ND | ND | | |
| SM-9X | 2.98 | ND | .054 | ND | | |
| SM-10X | .135 | ND | ND | ND | | |
| SM-11X | | | ND | ND | | |
| SM-12X | | | ND | ND | | |

## Dowling Seepage Meter Ammonia Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | Protective Action Limit Mg/L | Enforcement Standard Mg/L |
|---|---|---|---|---|---|---|
| SM-1Y | | | .037 | .042 | NA | NA |
| SM-2Y | | | .03 | .042 | | |
| SM-3Y | | | ND | .042 | | |
| SM-4Y | .287 | ND | ND | .042 | | |
| SM-5Y | | | .031 | .042 | | |
| SM-6Y | | | .131 | .042 | | |
| SM-7Y | 1.01 | ND | .043 | .042 | | |
| SM-8Y | | | ND | .042 | | |
| SM-9Y | | | .271 | .042 | | |
| SM-10Y | .76 | ND | | | | |
| SM-11Y | | | .096 | .042 | | |

## Amnicon Seepage Meter Nitrate Analysis 1996

**Table 5.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | Protective Action Limit Mg/L | Enforcement Standard Mg/L |
|---|---|---|---|---|---|---|
| SM-OL | ND | ND | .046 | ND | 2 | 10 |
| SM-2X | .01 | ND | ND | ND | | |
| SM-3X | | | .013 | ND | | |
| SM-4X | .01 | ND | .325 | ND | | |
| SM-5X | .011 | ND | ND | ND | | |
| SM-6X | | | ND | ND | | |
| SM-7X | | | | | | |
| SM-8X | | | ND | ND | | |
| SM-9X | .012 | ND | ND | ND | | |
| SM-10X | .073 | ND | ND | ND | | |
| SM-11X | | | ND | ND | | |
| SM-12X | | | .011 | ND | | |

## Dowling Seepage Meter Nitrate Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | Protective Action Limit Mg/L | Enforcement Standard Mg/L |
|---|---|---|---|---|---|---|
| SM-1Y | | | .024 | .014 | 2 | 10 |
| SM-2Y | | | .021 | .014 | | |
| SM-3Y | | | ND | .014 | | |
| SM-4Y | ND | ND | ND | .014 | | |
| SM-5Y | | | .024 | .014 | | |
| SM-6Y | | | .034 | .014 | | |
| SM-7Y | ND | ND | .028 | .014 | | |
| SM-8Y | | | .03 | .014 | | |
| SM-9Y | | | .027 | .014 | | |
| SM-10Y | .012 | ND | | | | |
| SM-11Y | | | .021 | .014 | | |

## Amnicon Seepage Meter Total Phosphorus Analysis 1996

**Table 6.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | Protective Action Limit Mg/L | Enforcement Standard Mg/L |
|---|---|---|---|---|---|---|
| SM-OL | | | .032 | .044 | NA | NA |
| SM-2X | .042 | .024 | .041 | .044 | | |
| SM-3X | | | .214 | .044 | | |
| SM-4X | .047 | .024 | | | | |
| SM-5X | .052 | .024 | .093 | .044 | | |
| SM-6X | | | .078 | .044 | | |
| SM-7X | | | | | | |
| SM-8X | | | .057 | .044 | | |
| SM-9X | .184 | .024 | .27 | .044 | | |
| SM-10X | .038 | .024 | .044 | .044 | | |
| SM-11X | | | .069 | .044 | | |
| SM-12X | | | .073 | .044 | | |

## Dowling Seepage Meter Total Phosphorus Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | Protective Action Limit Mg/L | Enforcement Standard Mg/L |
|---|---|---|---|---|---|---|
| SM-1Y | | | .106 | .044 | NA | NA |
| SM-2Y | | | .028 | .044 | | |
| SM-3Y | | | .123 | .044 | | |
| SM-4Y | .105 | .024 | .149 | .044 | | |
| SM-5Y | | | .178 | .044 | | |
| SM-6Y | | | .029 | .044 | | |
| SM-7Y | .137 | .024 | .115 | .044 | | |
| SM-8Y | | | .226 | .044 | | |
| SM-9Y | | | .194 | .044 | | |
| SM-10Y | .112 | .024 | | | | |
| SM-11Y | | | .143 | .044 | | |

## Amnicon Seepage Meter Orthophosphate Analysis 1996

**Table 7.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | Protective Action Limit Mg/L | Enforcement Standard Mg/L |
|---|---|---|---|---|---|---|
| SM-OL | .005 | .002 | ND | .006 | NA | NA |
| SM-2X | ND | .002 | .005 | .006 | | |
| SM-3X | | | .006 | .006 | | |
| SM-4X | .003 | .002 | | | | |
| SM-5X | .003 | .002 | .005 | .006 | | |
| SM-6X | | | .012 | .006 | | |
| SM-7X | | | | | | |
| SM-8X | | | .004 | .006 | | |
| SM-9X | .004 | .002 | ND | .006 | | |
| SM-10X | .012 | .002 | .002 | .006 | | |
| SM-11X | | | .002 | .006 | | |
| SM-12X | | | ND | .006 | | |

## Dowling Seepage Meter Orthophosphate Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | Protective Action Limit Mg/L | Enforcement Standard Mg/L |
|---|---|---|---|---|---|---|
| SM-1Y | | | .002 | .002 | NA | NA |
| SM-2Y | | | | | | |
| SM-3Y | | | ND | .002 | | |
| SM-4Y | | | .002 | .002 | | |
| SM-5Y | | | .015 | .002 | | |
| SM-6Y | | | .004 | .002 | | |
| SM-7Y | | | .004 | .002 | | |
| SM-8Y | | | .012 | .002 | | |
| SM-9Y | | | .005 | .002 | | |
| SM-10Y | | | | | | |
| SM-11Y | | | .003 | .002 | | |

### *Bacteria and Optical Brighteners in Seepage Meter Data*

Bacteria are trapped in the pore space between soil particles under septic systems. This entrapment or filtration is an important mechanism for removal of enteric bacteria from effluent. A clogging mat occurs at the interface between the drainage field and natural soils. This mat is formed in part because of bacterial activity and serves in turn to help trap enteric bacteria before entering the soil. Other important factors influencing the attenuation of bacteria include bacterial numbers in the effluent, soil texture, soil saturation, loading rates, temperature and bacterial type. Unsaturated flow beneath drainfields is important in ensuring slow travel, long residence time for bacteria in the unsaturated zone, good aeration, increased opportunity for contact between effluent and soil particles, opportunity for absorption of bacteria to soil particles and eventual die-off of bacteria.

As stated above, soil conditions, effluent loading, treatment system age and proximity to the water resources is of concern in the removal of enteric bacteria. The presence of these bacteria in monitoring wells is not only a indication of leaking treatment systems but is also a human health concern to lake property owners through potential contamination of drinking water wells.

Traditional groundwater sanitary indicators such as coliform bacteria and nitrate may be ambiguous as stand-alone indications of groundwater and lake contamination, especially if test results are variable, at or below background levels or negative (Spong et al. 1995). Staining and absorption limit fecal bacteria migration and survival, and reducing or denitrifying conditions can slow nitrogen oxidation to nitrite or reverse it (Bitton and Gerba, 1984). Negative sanitary tests alone do not prove that a water supply is uncontaminated without more extensive testing. Other quantitative pollution parameters indicative of septic contamination, including specific conductance and chloride also suffer from some ambiguity.

Optical brighteners are additives to laundry detergents and often contaminate groundwater. Its concentration may rapidly and inexpensively be determined by fluorescence techniques, and because its source is human waste water, its presence in groundwater serves as a direct indication of pollution from septic tanks, sewer leaks and landfills. Optical brightener determination occasionally suffers from background organic fluorescence. In this case, scanning fluorescence techniques and solid phase detection was employed. Solid phase detection relies on a solid phase media which preferentially sorbs and accumulates the optical brighteners over background dissolved organic material. This method has been used with great success in Minnesota. Fay et al. 1995 indicate that this method can be used with great success in organic waters and adds to the strength of studies that include the more traditional septic markers (i.e bacteria, $Cl^-$ etc.). This seepage fluorescence tag is non-intrusive to property owners in that it is present in raw effluent with no need to apply artificial dyes to the system. The optical brightener test performed by C.J. Owen and Associates was a presence (+), absence (-) test.

## Amnicon Seepage Meter Bacteria and Optical Brightener Analysis 1996

**Table 8.**

| SITE | 7/14 Optical Brighteners | 7/14 Level MFFCC | 7/14 F. Strep | 7/14 E.Coli | 9/22 MFFCC | 9/22 F. Strep | 9/22 E. Coli | 2/2/97 Optical Brighteners |
|---|---|---|---|---|---|---|---|---|
| SM-OL | + | | | | | | | - |
| SM-2X | - | <10 | <10 | <10 | | | | - |
| SM-3X | | | | | Removed | | | |
| SM-4X | - | <10 | <10 | <10 | | | | + |
| SM-5X | - | <10 | <10 | <10 | | | | |
| SM-6X | Removed | | | | | | | - |
| SM-7X | Removed | | | | | | | - |
| SM-8X | Removed | | | | | | | + |
| SM-9X | + | 10 (+) | <10 | <10 | | | | + |
| SM-10X | + | 10 (+) | 10 (+) | <10 | | | | + |
| SM-11X | + | | | | | | | + |
| SM-12X | Removed | | | | 20 (+) | 10 (+) | <10 | - |

## Dowling Seepage Meter Bacteria and Optical Brightener Analysis 1996

| SITE | 7/14 Optical Brighteners | 7/14 Level MFFCC | 7/14 F. Strep | 7/14 E.Coli | 9/22 MFFCC | 9/22 F. Strep | 9/22 E. Coli | 2/2/97 Optical Brighteners |
|---|---|---|---|---|---|---|---|---|
| SM-1Y | Removed | | | | 40 | <10 | 10 | + |
| SM-2Y | Removed | | | | | | | + |
| SM-3Y | + | 280 (+) | <10 | 260 (+) | <10 | 10 (+) | <10 | + |
| SM-4Y | - | | | | | | | - |
| SM-5Y | + | | | | | | | |
| SM-6Y | No Flow | | | | | | | - |
| SM-7Y | + | 30 (+) | <10 | <10 | | | | |
| SM-8Y | No Flow | | | | | | | + |
| SM-9Y | No Flow | | | | <10 | <10 | <10 | - |
| SM-10Y | + | | | | | | | - |
| SM-11Y | No Flow | | | | <10 | 20 (+) | <10 | + |

## Lake Amnicon/Dowling Bacterial Hot Spot Results (Appendix 1; Map 5-6)

### *Hot Spot Nutrient Data*

#### *Ammonia*

As stated previously, ammonia ($NH_3$-N), an inorganic form of nitrogen, is contained in fertilizers, septic system effluent and animal waste. It is also a product of bacterial decomposition of organic matter. Changes in the concentration of $NH_3$-N are the result of loading, decomposition of organic-N, and oxidation of $NH_3$-N to Nitrate-N.

The purpose of Hot Spot ammonia sampling was to determine area of concern, with elevated levels of nitrogen input to the lakes in the form of ammonia.

## Amnicon Hot Spot Ammonia Analysis 1996

**Table 9.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-1 | ND | ND | ND | ND | .132 |
| HS-5 | .033 | ND | .043 | ND | |
| HS-2 | ND | ND | ND | ND | .09 |
| HS-9 | | | ND | ND | |
| HS-8 | | | ND | ND | |
| HS-10 | | | ND | ND | |
| HS-7 | | | ND | ND | |
| HS-6 | | | .443 | ND | |
| HS-3 | .057 | ND | ND | ND | |
| HS-4 | ND | ND | ND | ND | |

## Dowling Hot Spot Ammonia Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-4 | ND | ND | .027 | .042 | |
| HS-5 | | | ND | .042 | |
| HS-1 | .047 | ND | .031 | .042 | |
| HS-2 | ND | ND | ND | .042 | |
| HS-6 | | | .055 | .042 | |
| HS-3 | ND | ND | .035 | .042 | |

### *Nitrate*

As stated previously, nitrate and nitrite are inorganic forms of nitrogen present in the environment and can be formed though the oxidation of $NH_3$-N by nitrifying bacteria (nitrification). Nitrate is one of the principal forms of nitrogen used by algae for growth. Also of concern are the toxic effects of nitrate in drinking water, which can cause methemoglobinemia or "blue baby syndrome". Nitrite concentrations are generally small in natural waters and therefore nitrate is usually expressed as Nitrate+Nitrite-N. Nitrate+Nitrite-N concentrations may vary seasonally and with biological activity.

Hot spot nitrate concentrations were determined to identify areas with elevated levels of nitrogen input to the lakes in the form of nitrate.

## Amnicon Hot Spot Nitrate Analysis 1996

**Table 10.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-1 | ND | ND | ND | ND | .32 |
| HS-5 | .117 | ND | .375 | ND | |
| HS-2 | ND | ND | ND | ND | .124 |
| HS-9 | | | ND | ND | |
| HS-8 | | | ND | ND | |
| HS-10 | | | ND | ND | |
| HS-7 | | | ND | ND | |
| HS-6 | | | .352 | ND | |
| HS-3 | ND | ND | ND | ND | |
| HS-4 | ND | ND | ND | ND | |

## Dowling Hot Spot Nitrate Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-4 | .013 | ND | .023 | .014 | |
| HS-5 | | | .026 | .014 | |
| HS-1 | .067 | ND | .021 | .014 | |
| HS-2 | ND | ND | .027 | .014 | |
| HS-6 | | | .027 | .014 | |
| HS-3 | ND | ND | .023 | .014 | |
| | | | | | |
| HS-6 | | | | | |
| HS-3 | | | | | |
| HS-4 | | | | | |

### *Phosphorus*

As stated previously in this report, phosphorus is a fundamental nutrient in the growth of most plants, whether on land or in the water. As such, the amount present in the water greatly affects the amount of algae and other aquatic plants present in a lake. Origins of phosphorus include fertilizers, animal wastes, septic systems, plant decomposition, soil and sediment.

Phosphorus is present in an assortment of forms in the environment. Total phosphorus (TP) provides a measurement of the total concentration of phosphorus present in a system. TP is used in eutrophication models and mass loading calculations to predict productivity and the magnitude of phosphorus inputs. Ortho-phosphorus (OP; also known as soluble reactive phosphorus SRP) is the available form of phosphorus for use by algae and aquatic plants. The intention of the Hot Spot sampling was to identify potential point sources of nutrients entering the lake.

## Amnicon Hot Spot Total Phosphorus Analysis 1996

**Table 11.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-1 | .02 | .022 | .02 | .022 | .32 |
| HS-5 | .023 | .022 | .027 | .022 | |
| HS-2 | .019 | .022 | .05 | .022 | .124 |
| HS-9 | | | .022 | .022 | |
| HS-8 | | | .024 | .022 | |
| HS-10 | | | .075 | .022 | |
| HS-7 | | | .029 | .022 | |
| HS-6 | | | .282 | .022 | |
| HS-3 | .062 | .022 | .11 | .022 | |
| HS-4 | .016 | .022 | .019 | .022 | |

## Dowling Hot Spot Total Phosphorus Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-4 | .039 | .03 | .218 | .044 | |
| HS-5 | | | .11 | .044 | |
| HS-1 | .046 | .03 | .092 | .044 | |
| HS-2 | .023 | .03 | .099 | .044 | |
| HS-6 | | | .08 | .044 | |
| HS-3 | .026 | .03 | .132 | .044 | |

## Amnicon Hot Spot Orthophosphate Analysis 1996

**Table 12.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-1 | ND | .002 | ND | .002 | .002 |
| HS-5 | .006 | .002 | .006 | .002 | |
| HS-2 | ND | .002 | ND | .002 | .002 |
| HS-9 | | | ND | .002 | |
| HS-8 | | | ND | .002 | |
| HS-10 | | | .003 | .002 | |
| HS-7 | | | .004 | .002 | |
| HS-6 | | | .006 | .002 | |
| HS-3 | .005 | .002 | ND | .002 | |
| HS-4 | ND | .002 | ND | .002 | |

### Dowling Hot Spot Orthophosphate Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 9/22 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-4 | ND | .002 | .004 | .011 | |
| HS-5 | | | .002 | .011 | |
| HS-1 | ND | .002 | .003 | .011 | |
| HS-2 | ND | .002 | .002 | .011 | |
| HS-6 | | | .002 | .011 | |
| HS-3 | ND | .002 | .004 | .011 | |

## *Ions and Conductivity at Hot Spots*

### *Conductivity*

Conductivity (or specific conductance) and is an indirect measurement of total dissolved solids (TDS). Variations in Hot Spot conductivity may indicate ion rich runoff. The greatest value of specific conductance is the estimation of the total concentration of dissolved ions in the water, which is related to water fertility. Specific conductance provides a quick check for alterations in total water quality due to the addition of pollutants (Lind, 1979). The objective of performing a Hot Spot conductivity sampling for Lake Amnicon and Dowling was to correlate spikes in surface water conductance with possible point source run off contamination to identify and prioritize sites exhibiting signs of excessive nutrient ion input.

Nearshore conductivity results indicate no significant elevation in conductivity (10-20% higher than surface water-deep hole readings). These results indicate a low probability of widespread run off problems for these sites.

### Amnicon Hot Spot Conductivity Analysis 1996

**Table 13.**

| SITE | 7/14 Level Uhmos | 7/14 Ambient Uhmos | 9/22 Level Uhmos | 9/20 Ambient Uhmos |
|---|---|---|---|---|
| HS-1 | 42 | 50 | 50 | 52 |
| HS-5 | 20 | 50 | 65 | 52 |
| HS-2 | 41 | 50 | 50 | 52 |
| HS-9 | | | 50 | 52 |
| HS-8 | | | 50 | 52 |
| HS-10 | | | 50 | 52 |
| HS-7 | | | 51 | 52 |
| HS-6 | | | 56 | 52 |
| HS-3 | 45 | 50 | 50 | 52 |
| HS-4 | 45 | 50 | 50 | 52 |

### Dowling Hot Spot Conductivity Analysis 1996

| SITE | 7/14 Level Uhmos | 7/14 Ambient Uhmos | 9/22 Level Uhmos | 9/20 Ambient Uhmos |
|---|---|---|---|---|
| HS-4 | 35 | 40 | | |
| HS-5 | | | | |
| HS-1 | 35 | 40 | | |
| HS-2 | 32 | 40 | | |
| HS-6 | | | | |
| HS-3 | 30 | 40 | | |

### Amnicon Hot Spot Metals Analysis 1996

**Table 14.**

| Site | Chromium ug/l | PAL ug/l | Copper ug/l | PAL ug/l | Lead ug/l | PAL ug/l | Zinc ug/l | PAL ug/l |
|---|---|---|---|---|---|---|---|---|
| HS-1 | ND | 10000 | 3 | 130000 | ND | 1500 | 85 | 2500 |
| HS-2 | ND | | 3 | | ND | | ND | |
| HS-3 | ND | | 4 | | 1 | | 44 | |
| HS-4 | ND | | ND | | ND | | ND | |

### Dowling Hot Spot Metals Analysis 1996

| Site | Chromium ug/l | PAL ug/l | Copper ug/l | PAL ug/l | Lead ug/l | PAL ug/l | Zinc ug/l | PAL ug/l |
|---|---|---|---|---|---|---|---|---|
| HS-1 | ND | 10000 | 4 | 130000 | ND | 1500 | 25 | 2500 |
| HS-2 | ND | | 4 | | 1 | | 80 | |
| HS-3 | ND | | 3 | | 3 | | 46 | |
| HS-4 | ND | | 3 | | 3 | | ND | |

### Amnicon Hot Spot Chloride Analysis 1996

**Table 15.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 10/28 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-1 | | | | 2.4 | 3.36 |
| HS-5 | 2.3 | 2.5 | | | |
| HS-2 | | | | 2.4 | 2.97 |
| HS-9 | | | | | |
| HS-8 | | | | | |
| HS-10 | | | | | |
| HS-7 | | | | | |
| HS-6 | | | | | |
| HS-3 | | | | | |
| HS-4 | | | | | |

## Dowling Hot Spot Chloride Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 10/28 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-4 | | | | | |
| HS-5 | | | | | |
| HS-1 | | | 1 | 2.4 | |
| HS-2 | | | 1.1 | 2.4 | |
| HS-6 | | | | | |
| HS-3 | | | | | |

This data was provided gratis by the Wisconsin Department of Health and is not of adequate number to make valid conclusions.

## Amnicon Hot Spot Iron Analysis 1996

**Table 16.**

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 10/28 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-1 | | | | | |
| HS-5 | 1.8 | .2 | | | |
| HS-2 | | | | | |
| HS-9 | | | | | |
| HS-8 | | | | | |
| HS-10 | | | | | |
| HS-7 | | | | | |
| HS-6 | | | | | |
| HS-3 | | | | | |
| HS-4 | | | | | |

## Dowling Iron Analysis 1996

| SITE | 7/14 Level Mg/L | 7/14 Ambient Mg/L | 9/22 Level Mg/L | 10/28 Ambient Mg/L | 2/2/97 Level Mg/L |
|---|---|---|---|---|---|
| HS-4 | | | | | |
| HS-5 | | | | | |
| HS-1 | | | .76 | .61 | |
| HS-2 | | | .76 | .61 | |
| HS-6 | | | | | |
| HS-3 | | | | | |

This data was provided gratis by the Wisconsin Department of Health and is not of adequate number to make valid conclusions on its meaning.

### *Bacteria*

Lake Amnicon/Dowling can be classified as a direct contact recreational lake. As such, indicators of potential contamination are of interest. The standard for recreational use is as follows:

- ***Fecal Coliform* counts shall not exceed 200 per 100ml as a geometric mean on not less than 5 samples per month, not exceed 400 per 100ml in more than 10% of all samples taken during any month.**

The intent of this sampling regime was not to determine compliance to these recreational use standards but to look for possible contamination and spatial distribution of this contamination, if present. Sampling on Lake Amnicon/Dowling was performed on a select number of Hot Spots. A map of sampling sites is located in Appendix 1: Map 5-6. Samples for Lake Amnicon/Dowling exhibited *Fecal Coliform* ranges from < 10 to 130 cells per 100ml. While samples were limited to less than four samplings over several months, (not meeting the criteria for the Administrative Code) cell counts were all below the 200 cells per 100 ml for body contact recreation. *Fecal Streptococci* in general, were low (a trend did hold true that when there was a detectable level of *Fecal Coliform*, there was also a detectable level of Streptococci). All levels of bacteria were below the standards, indicating that ratio analysis of Fecal coliform/Fecal streptococcus would not give reliable results.

**Amnicon Hot Spot Bacteria Analysis 1996**

**Table 17.**

| SITE | 7/14 Level MFFCC | 7/14 F. Strep | 7/14 E.Coli | 9/22 MFFCC | 9/22 F. Strep | 9/22 E. Coli |
|---|---|---|---|---|---|---|
| HS-1 | 40 | 10 | 30 | <10 | <10 | <10 |
| HS-5 | 130 | 110 | 100 | <10 | 240 | 10 |
| HS-2 | 10 | <10 | 30 | <10 | 10 | <10 |
| HS-9 | | | | <10 | <10 | <10 |
| HS-8 | | | | <10 | 10 | <10 |
| HS-10 | | | | 10 | <10 | <10 |
| HS-7 | | | | <10 | 60 | <10 |
| HS-6 | | | | 10 | 30 | <10 |
| HS-3 | | | | 20 | <10 | <10 |
| HS-4 | 20 | 30 | <10 | <10 | <10 | <10 |

Dowling Bacteria Analysis 1996

| SITE | 7/14 Level MFFCC | 7/14 F. Strep | 7/14 E.Coli | 9/22 MFFCC | 9/22 F. Strep | 9/22 E. Coli |
|---|---|---|---|---|---|---|
| HS-4 | 130 | <10 | 160 | <10 | <10 | <10 |
| HS-5 | | | | <10 | <10 | <10 |
| HS-1 | 30 | 30 | 10 | <10 | 60 | <10 |
| HS-2 | 20 | 10 | 30 | <10 | 20 | <10 |
| HS-6 | | | | <10 | <10 | <10 |
| HS-3 | <10 | 10 | 60 | 40 | 70 | <10 |

## Sediment Summary

### *Sediment Oxygen Demand (SOD)*

Sediments are generally in a reduced chemical state and have potential to remove oxygen from the overlying water. This results from the migration of dissolved oxygen to the sediment water interface followed by subsequent chemical reaction and /or the migration of the reduced chemical species (ferrous iron, manganous manganese and sulfide) from the sediments to the overlying water followed by subsequent oxidation. In addition to chemical processes, biological organisms in the sediment consume oxygen which has diffused into the sediment from the overlying water. The sediment oxygen demand procedure characterizes sediments in terms of the rate of exertion of oxygen demand on overlying water. The value of SOD for Amnicon/Dowling Lake is moderate for a temperate system (Table 18).

### *Sediment Biochemical Oxygen Demand (S-BOD)*

The biochemical oxygen demand (BOD) test is an empirical bioassay type procedure that measures the dissolved oxygen (DO) consumed by microbial organisms while assimilating and oxidizing the organic matter present in the sediment. The Sediment BOD for Amnicon/Dowling lake is in the moderate level, indicating a system that has a medium DO demand on overlying water due to microbial action (Table 18).

### *Volatile Suspended Solids (VSS)*

A dried sediment sample is ignited to a constant weight at 550°C. The remaining solids represent the percent of a sediment sample that is organic in nature. This organic component is important because it is the fraction that creates the oxidizable material for S-BOD and SOD. The level of VSS for Amnicon/Dowling is typical of a mesotrophic lake with moderate hypolimnetic oxygen demand (Table 18).

### *Sediment TP*

Sediment TP is a rough estimate of the potential amount of phosphorus available for release to the overlying water under anoxic conditions. The sediment TP level for Amnicon/Dowling Lake is related to the VSS in the system. The moderate level of VSS also reflects the moderate level of sediment TP (Table 18).

**Amnicon Sediment**

**Table 18.**

| SOD mg $O_2/m^2$/Day | S-BOD mg/Kg/ Wet Wt. | VSS | Sed-TP mg/Kg/Dry Wt |
|---|---|---|---|
| 140 | 315.4 | Ref: 20% | Ref. 1,051 |
| | | 32% | 3,534 |

**Dowling Sediment**

| SOD mg $O_2/m^2$/Day | S-BOD mg/Kg/ Wet Wt. | VSS | Sed-TP mg/Kg/Dry Wt |
|---|---|---|---|
| 112 | 360.2 | Ref: 20% | Ref. 1,051 |
| | | 36% | 2,234 |

## CONCLUSIONS

- Clearly, results from this study indicate that the lakes continue their status as eutrophic with occasional anoxia in Lake Amnicon, restricted light penetration in both lakes and the presence of nuisance algal blooms relatively early in the year. Additionally, the limited winter sampling indicates a moderately high rate of oxygen depletion in the water column during ice cover (of concern to the fisheries of both lakes). Additional improvements in the manner in which lakeshore/watershed residences relate to the lakes needs to be addressed. A continued lack of sound shoreline best management practices (i.e. BMP's) may undoubtedly accelerate the process of eutrophication.

- Nutrient data indicate a system sensitive to external and internal additions of N and P. Nutrient ratio analysis further support this conclusion.

- Studies conducted by two independent environmental consultant groups, over three years, (C.J. Owen and Associates and A.W. Research Laboratories) have indicated that both Lake Amnicon and Lake Dowling are currently being impacted by above ground as well as below ground contamination. The baseline data from this study further support this conclusion.

- Groundwater data indicates the presence of bacteria in the groundwater entering both lakes. This indicates human based contamination of groundwater and may also be of a public health concern for those obtaining drinking water from this aquifer.

- Passive tracers in the groundwater entering both Lake Amnicon and Dowling show indications of human contamination.

## Recommendations

The following recommendations are made by C.J. Owen and Associates as a result of the 1996-97 Lake Amnicon/Dowling management project:

1. Continue the in-lake physical, chemical and biological monitoring, to be accomplished by district members (DNR Planning Grant 1997-98).

2. Establish a monitoring program for drinking water wells for evaluation of compliance to standards.

3. Determine best course of action for wastewater treatment for Lake Amnicon and Dowling watershed.

4. Continue and expand lakeshore BMPs and review short summer provided by A.W. Research Laboratories (i.e. Groundtruthing Summary Appendix 5).

## REFERENCES

Carlson, R.E. 1977. A trophic state index for lakes. Limnol. Oceanogr. 22:361-369.

Cattaneo, A. 1987. Periphyton in lakes of different trophy. Can. J. Fish. Aquat. Sci. 44:296-303.

Collins, G.B. and C.I. Weber. 1978. Phycoperiphyton (algae) as indicators of water quality. Transactions of the American Microscope Society. 97:36-43.

EPA 1989. Handbook of Methods for Acid Deposition Studies. Field Operations for Surface Water Chemistry. EPA/600/4-89/020. U.S. EPA, Washington, D.C.

Gersberg, R.M., S. Hacl;y, and C.R. Goldman. 1980. Las Vegas Valley Water Quality Program. Bioassay Task Final Report. Ecological Research Associates, Davis, CA. Submitted to Brown and Caldwell Consulting Engineers, Sacromento, CA.

Goldman, C.R. and deAmezaga, E. 1975. Primary productivity in the littoral zone of Lake Tahoe, California-Nevada. Symp. Biol. Hungary 15:49-62.

Goldman, C.R. 1979. Lake Tahoe: an oligotrophic lake's response to nutrient loading. Lakes Pollution and Recovery Proc. Inter. Congr. Europ. Wat. Pollut. Contr. Assoc. Rome. April 1979, pp. 249-254.

Kellar, P., S. Paulson and L. Paulson. 1981.Methods for biological, chemical and physical analyses in reservoirs. Lake Mead Limnological Research Center Technical Rep. No. 5. University of Nevada, Las Vegas.

Lind, O.T. 1985. Handbook of common methods in limnology. Kendall/Hunt Publishing Co. Dubuque, IA.

Loeb, S.L. 1986. Algal biofouling of oligotrophic Lake Tahoe: Causal factors affecting production. In: Alagl Biofouling. L.V. Evans and K.D. Hoagland (eds.). Elsevier Science Publishers B.V., Amsterdam, The Netherlands. Chapter 11:159-173.

Loeb, S.L., Aloi, J.E. and S.H. Hackley. 1986. Littoral Zone Investigations, Lake Tahoe 1982-1985-Periphyton. Institute of Ecology - Division of Environmental Studies, University of California, Davis, CA. May 14, 1986. 158 pp.

Morris, D. and W. Lewis. 1988. Phytoplankton nutrient limitation in Colorado mountain lakes. Freshwater Biology 20:315-327.

OECD (Organization for Economic Cooperation and Development). 1982. Eutrophication of Waters. Monitoring, assessment and control. Paris, 154 p.

## REFERENCES CONT.

Sakamoto, M. 1966. Primary production by the phytoplankton community in some Japanese lakes and it dependence on lake depth. Arch. Hydrobiol. 61:1-28.

Shortreed, K.S., Costella, A.C. and J.G. Stockner. 1984. Periphyton biomass and species composition in 21 B.C. lakes: Seasonal abundance and response to whole-lake nutrient additions. Canadian Journal of Botany. 62:1022-1031.

Smith, V.H. 1979. Nutrient dependence on primary productivity in lakes. Limnol. Oceanogr. 24:1051-1064.

Stockner, J.G. and F.A.J. Armstrong. 1971. Periphyton of the Experimental Lakes Area, northwestern Ontario. Journal of the Fisheries Research Board of Canada 28:215-229.

Redfield, A.C. 1958. The biological control of chemical factors in the environment. Am. Sci. 46:205-221.

Rhee G-Y. and I.J. Gothham. 1980. Optimum N:P ratios and co-existence of planktonic algae. J. Phycology 16:486-489.

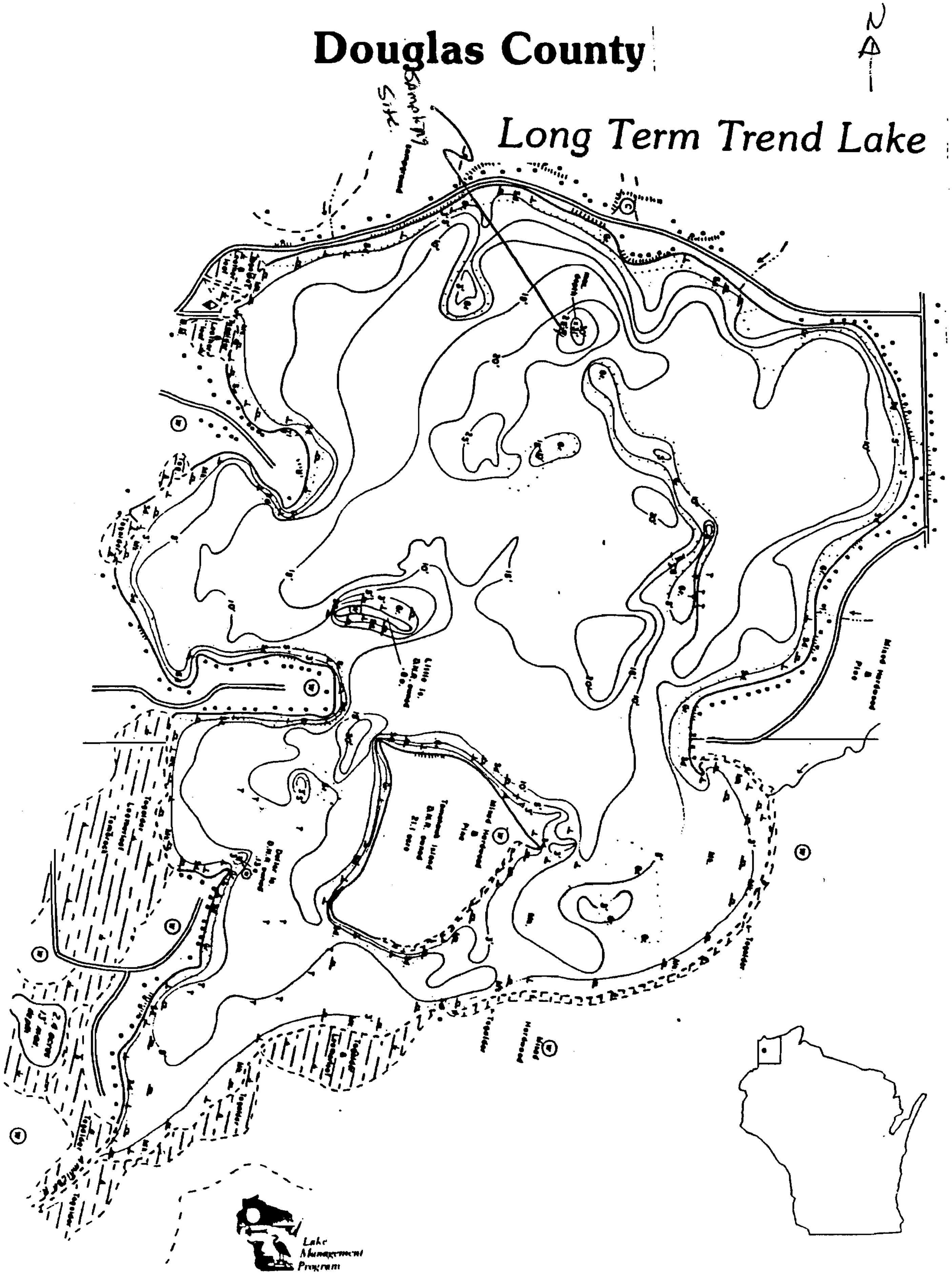
Wetzel, R.G. 1983. Limnology (2nd Ed.). W.B. Saunders, Co. Philadelphia, PA.

# Appendix 1.
# Map Sites

# AMNICON LAKE

## Douglas County

*Long Term Trend Lake*



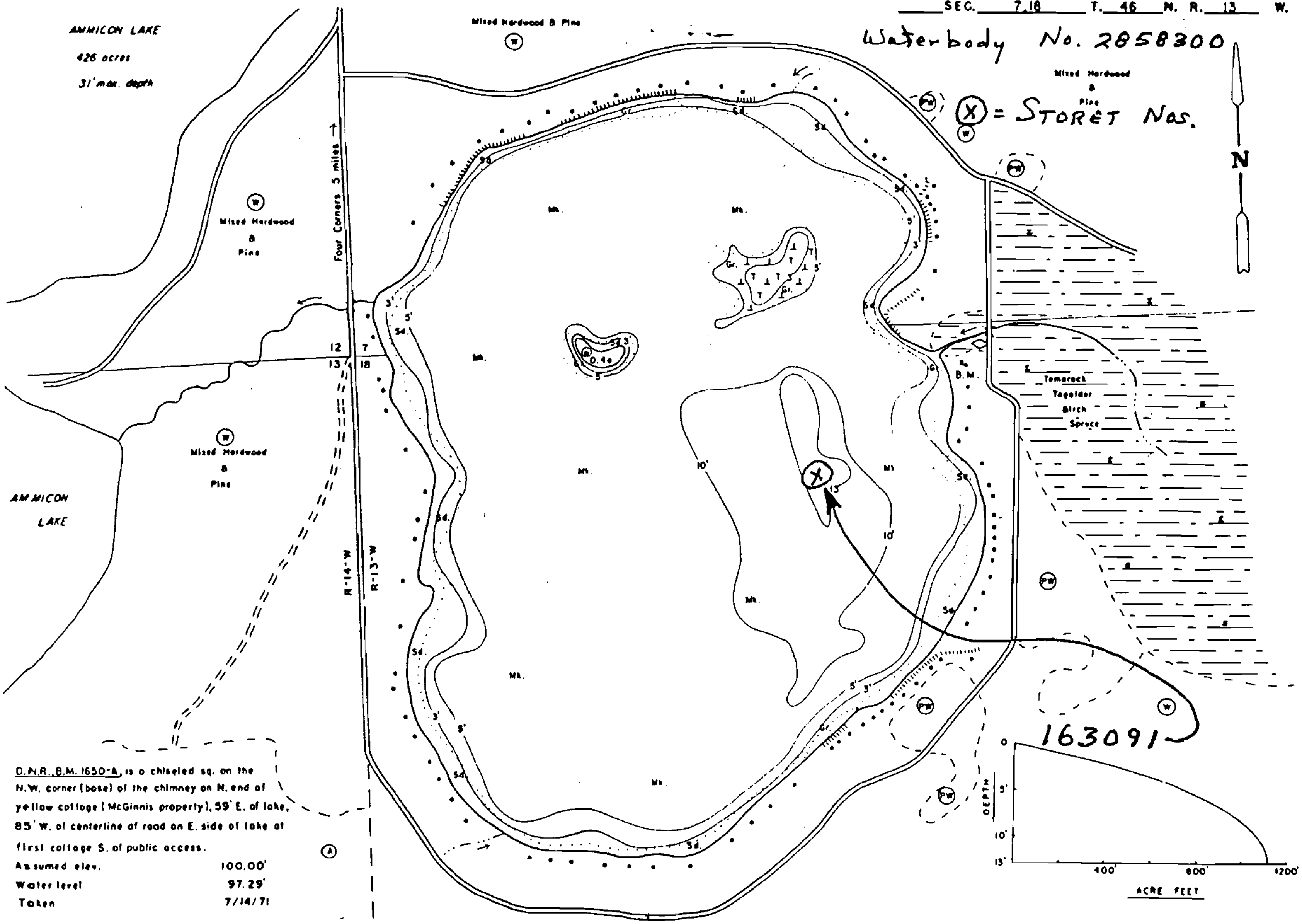
STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

# LAKE SURVEY MAP

DOWLING LAKE
DOUGLAS COUNTY
SEC. 7,18 T. 46 N. R. 13 W.

Waterbody No. 2858300

(X) = STORET Nos.



D.N.R. B.M. 1650-A, is a chiseled sq. on the N.W. corner (base) of the chimney on N. end of yellow cottage (McGinnis property), 59' E. of lake, 85' W. of centerline of road on E. side of lake at first cottage S. of public access.

| | |
|---|---|
| Assumed elev. | 100.00' |
| Water level | 97.29' |
| Taken | 7/14/71 |

EQUIPMENT RECORDING SONAR MAPPED JULY (MONTH) 1971 (YEAR)

TOPOGRAPHIC SYMBOLS

| | | | |
|---|---|---|---|
| Ⓑ | Brush | ıIIIIIı | Steep slope |
| (PW) | Partially wooded | - - - | Indefinite shoreline |
| Ⓦ | Wooded | | Marsh |
| Ⓒ | Cleared | | Spring |
| Ⓟ | Pastured | | Intermittent stream |
| Ⓐ | Agricultural | | Permanent inlet |
| B.M. | Bench Mark | | Permanent outlet |
| ■ | Dwelling | | Dam |
| ▣ | Resort | D.N.R. | State owned land |
| ▣ | Camp | | |

LAKE BOTTOM SYMBOLS

| | | | |
|---|---|---|---|
| P. | Peat | B | Boulders |
| Mk. | Muck | | Stumps & Snags |
| C. | Clay | | Rock danger to navigation |
| M. | Marl | T | Submergent vegetation |
| Sd. | Sand | ⊥ | Emergent vegetation |
| St. | Silt | | Floating vegetation |
| Gr. | Gravel | | Brush shelters |
| R. | Rubble | | |
| Bc | Bedrock | | |

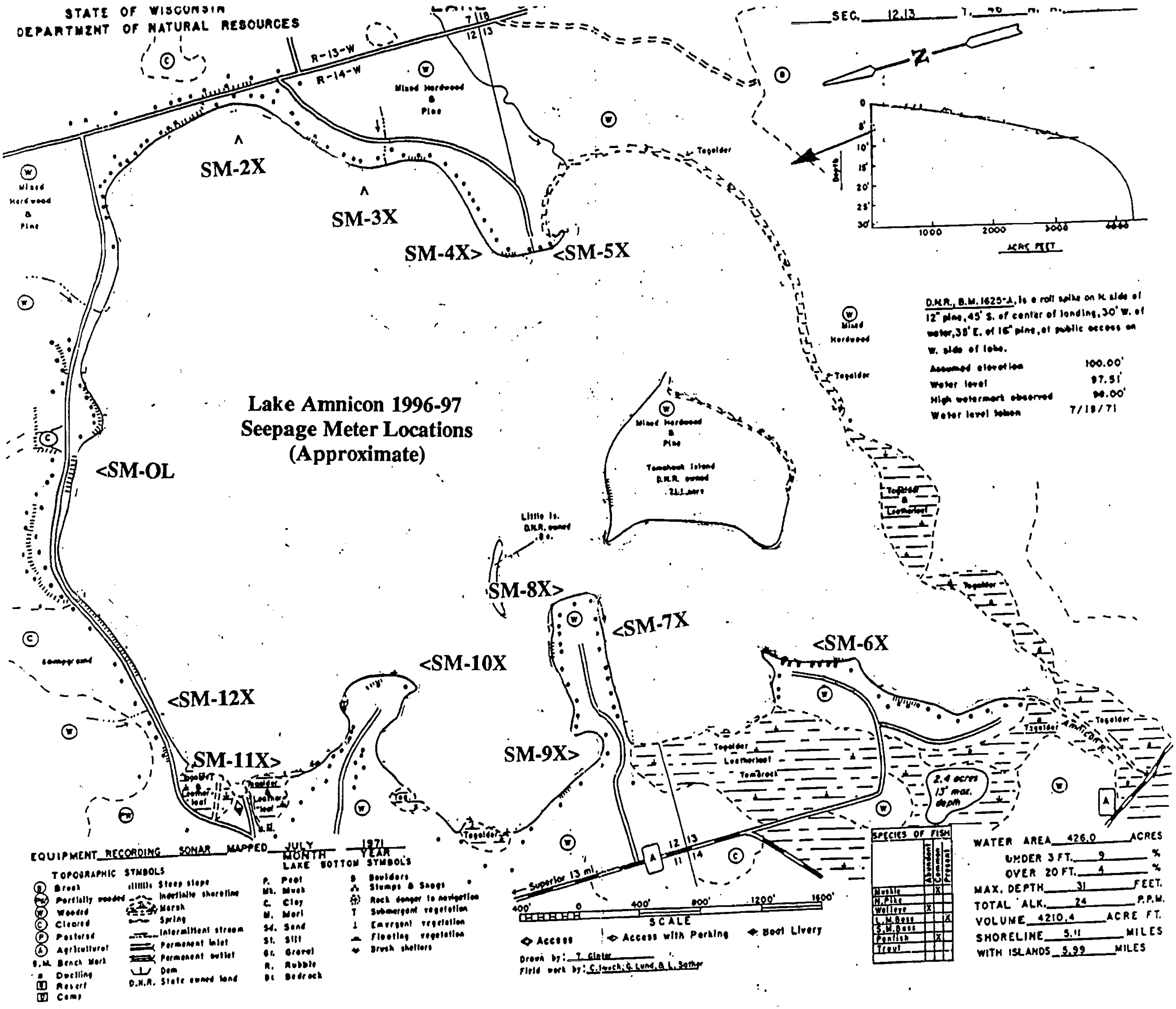
300' 0 300' 600' 900' 1200'
SCALE

◆ Access ◆ Access with Parking ◆ Boat Livery

Drawn by: T. Ginder
Field work by: C. Busch, G. Lund, & L. Seither

| SPECIES OF FISH | Abundant | Common | Present |
|---|---|---|---|
| Muskie | | X | |
| N. Pike | | | |
| Walleye | | X | |
| L.M. Bass | | | X |
| S.M. Bass | | | |
| Panfish | | X | |
| Trout | | | |
| | | | |

WATER AREA 153.8 ACRES
UNDER 3 FT. 8 %
OVER 20 FT. 0 %
MAX. DEPTH 13 FEET.
TOTAL ALK. 22 P.P.M.
VOLUME 1113.3 ACRE FT.
SHORELINE 1.95 MILES
WITH ISLAND 2.06 MILES



Lake Amnicon 1996-97
Seepage Meter Locations
(Approximate)

D.N.R., B.M. 1625-A, is a rail spike on N. side of 12" pine, 45' S. of center of landing, 30' W. of water, 38' E. of 16" pine, at public access on W. side of lake.

| | |
|---|---|
| Assumed elevation | 100.00' |
| Water level | 97.51' |
| High watermark observed | 98.00' |
| Water level taken | 7/19/71 |

EQUIPMENT RECORDING SONAR MAPPED JULY 1971
MONTH YEAR

TOPOGRAPHIC SYMBOLS

| | | | |
|---|---|---|---|
| Ⓑ | Brush | ‖‖‖‖ | Steep slope |
| Ⓟⓦ | Partially wooded | | Indefinite shoreline |
| Ⓦ | Wooded | | Marsh |
| Ⓒ | Cleared | | Spring |
| Ⓟ | Pastured | | Intermittent stream |
| Ⓐ | Agricultural | | Permanent inlet |
| B.M. | Bench Mark | | Permanent outlet |
| ■ | Dwelling | | Dam |
| R | Resort | D.N.R. | State owned land |
| C | Camp | | |

LAKE BOTTOM SYMBOLS

| | | | |
|---|---|---|---|
| P. | Peat | B | Boulders |
| Mk. | Muck | | Stumps & Snags |
| C. | Clay | | Rock danger to navigation |
| M. | Marl | T | Submergent vegetation |
| Sd. | Sand | ⊥ | Emergent vegetation |
| St. | Silt | | Floating vegetation |
| Gr. | Gravel | ◆ | Brush shelters |
| R. | Rubble | | |
| Bk. | Bedrock | | |

◇ Access
◇ Access with Parking
◆ Boat Livery

Drawn by: T. Ginter
Field work by: C. Iwuch, G. Lund, & L. Sather

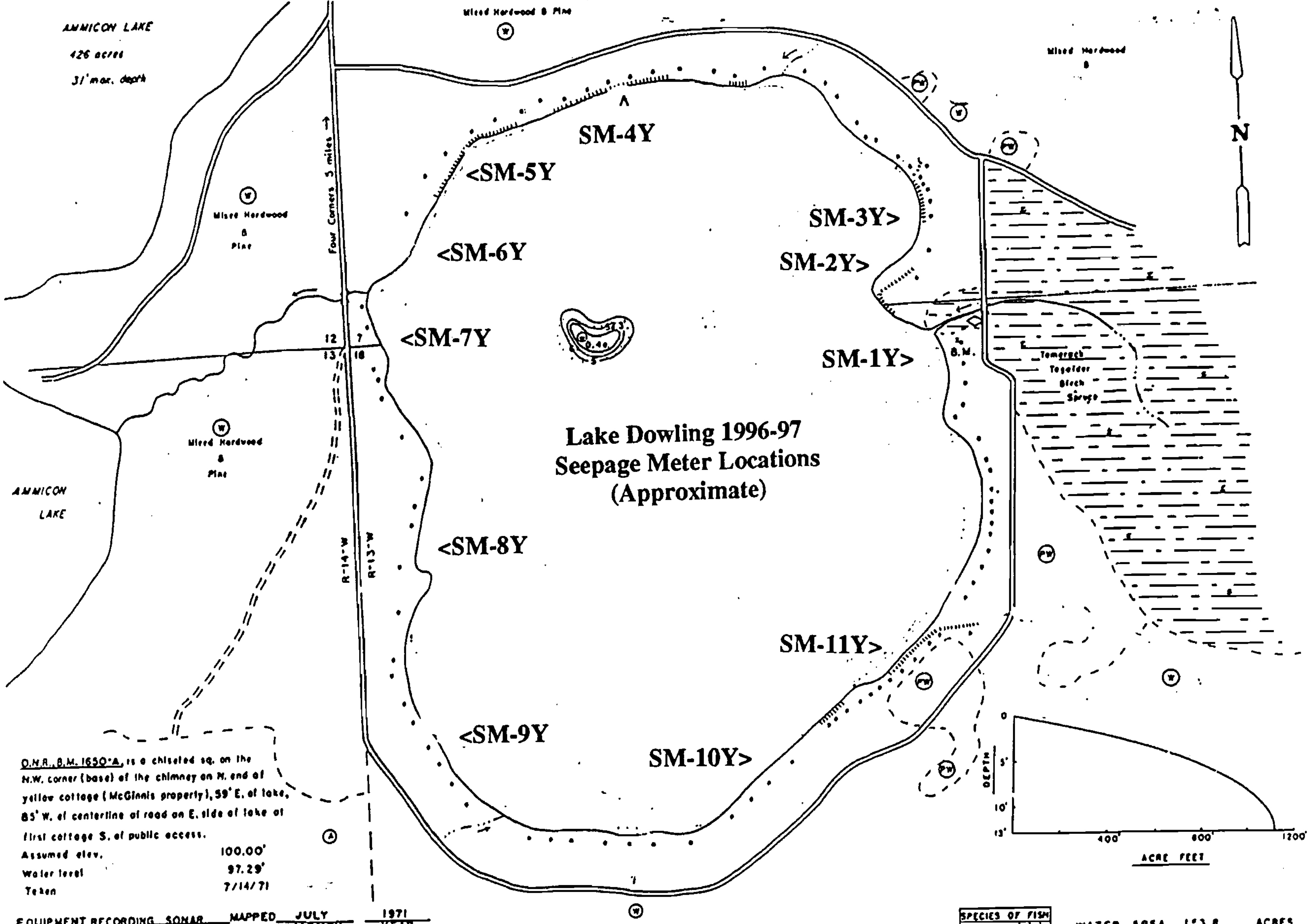
| SPECIES OF FISH | Abundant | Common | Present |
|---|---|---|---|
| Muskie | | X | |
| N. Pike | | | |
| Walleye | X | | |
| L.M. Bass | | | X |
| S.M. Bass | | | |
| Panfish | | X | |
| Trout | | | |
| | | | |

WATER AREA 426.0 ACRES
UNDER 3 FT. 9 %
OVER 20 FT. 4 %
MAX. DEPTH 31 FEET.
TOTAL ALK. 24 P.P.M.
VOLUME 4210.4 ACRE FT.
SHORELINE 5.11 MILES
WITH ISLANDS 5.99 MILES

STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

# LAKE SURVEY MAP

DOWLING LAKE
DOUGLAS COUNTY
SEC. 7,18 T. 46 N. R. 13 W.



D.N.R. B.M. 1650-A, is a chiseled sq. on the N.W. corner (base) of the chimney on N. end of yellow cottage (McGinnis property), 59' E. of lake, 85' W. of centerline of road on E. side of lake at first cottage S. of public access.

| | |
|---|---|
| Assumed elev. | 100.00' |
| Water level | 97.29' |
| Taken | 7/14/71 |

EQUIPMENT RECORDING SONAR MAPPED JULY (MONTH) 1971 (YEAR)

TOPOGRAPHIC SYMBOLS

| | | | |
|---|---|---|---|
| (B) | Brush | ıllllı | Steep slope |
| (PW) | Partially wooded | | Indefinite shoreline |
| (W) | Wooded | | Marsh |
| (C) | Cleared | | Spring |
| (P) | Pastured | | Intermittent stream |
| (A) | Agricultural | | Permanent inlet |
| B.M. | Bench Mark | | Permanent outlet |
| ▪ | Dwelling | | Dam |
| ▣ | Resort | D.N.R. | State owned land |

LAKE BOTTOM SYMBOLS

| | | | |
|---|---|---|---|
| P. | Peat | B | Boulders |
| Mk. | Muck | | Stumps & Snags |
| C. | Clay | | Rock danger to navigation |
| M. | Marl | T | Submergent vegetation |
| Sd. | Sand | | Emergent vegetation |
| St. | Silt | | Floating vegetation |
| Gr. | Gravel | | Brush shelters |
| R. | Rubble | | |
| Br | Bedrock | | |

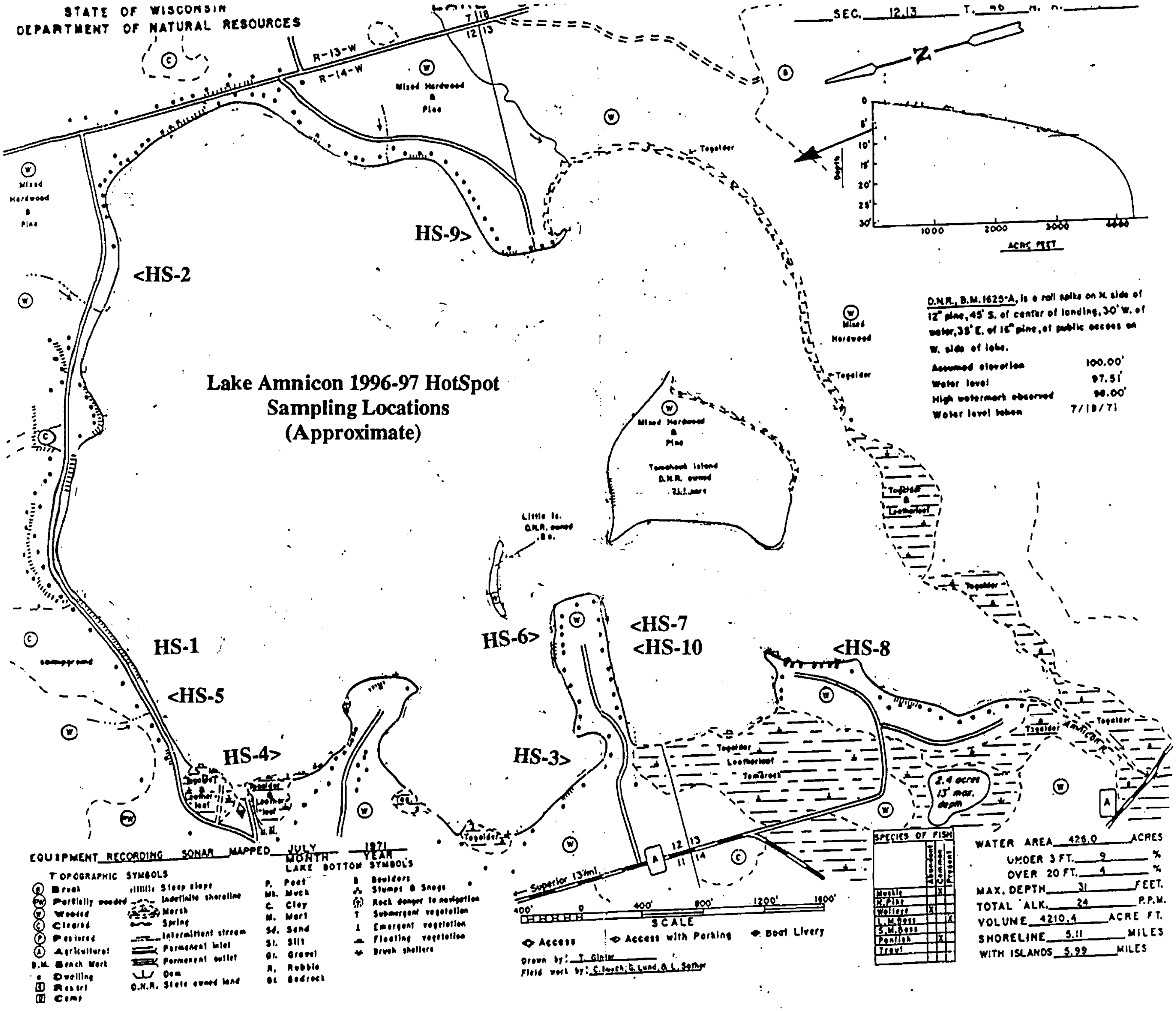
SCALE 300' 0 300' 600' 900' 1200'

◇ Access ◇ Access with Parking ◆ Boat Livery

Drawn by: T. Ginder
Field work by: C. Busch, G. Lund, & L. Sather

| SPECIES OF FISH | Abundant | Common | Present |
|---|---|---|---|
| Muskie | | X | |
| N. Pike | | | |
| Walleye | | X | |
| L.M. Bass | | | X |
| S.M. Bass | | | |
| Panfish | | X | |
| Trout | | | |
| | | | |

WATER AREA 153.8 ACRES
UNDER 3 FT. 8 %
OVER 20 FT. 0 %
MAX. DEPTH 13 FEET.
TOTAL ALK. 22 P.P.M.
VOLUME 1113.3 ACRE FT.
SHORELINE 1.95 MILES
WITH ISLAND 2.06 MILES

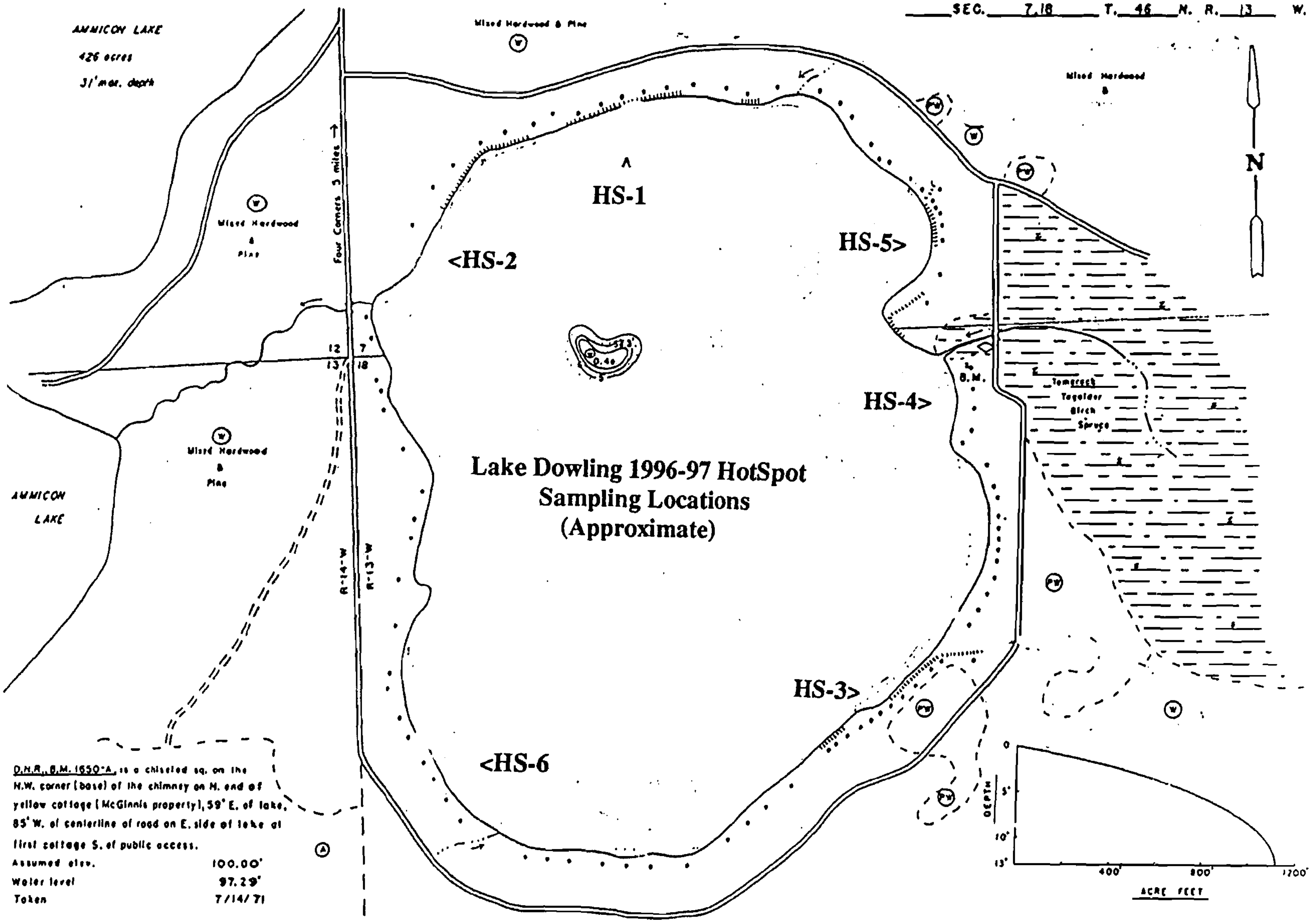


Lake Amnicon 1996-97 HotSpot Sampling Locations (Approximate)

STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

# LAKE SURVEY MAP

DOWLING LAKE  DOUGLAS COUNTY
SEC. 7,18 T. 46 N. R. 13 W.



## Lake Dowling 1996-97 HotSpot Sampling Locations (Approximate)

D.N.R. B.M. 1650-A, is a chiseled sq. on the N.W. corner (base) of the chimney on N. end of yellow cottage (McGinnis property), 59' E. of lake, 85' W. of centerline of road on E. side of lake at first cottage S. of public access.

| | |
|---|---|
| Assumed elev. | 100.00' |
| Water level | 97.29' |
| Taken | 7/14/71 |

EQUIPMENT RECORDING SONAR MAPPED JULY MONTH 1971 YEAR

TOPOGRAPHIC SYMBOLS
- Ⓑ Brush
- ⓅⓌ Partially wooded
- Ⓦ Wooded
- Ⓒ Cleared
- Ⓟ Pastured
- Ⓐ Agricultural
- B.M. Bench Mark
- • Dwelling
- Ⓡ Resort
- Ⓒ Camp
- Steep slope
- Indefinite shoreline
- Marsh
- Spring
- Intermittent stream
- Permanent inlet
- Permanent outlet
- Dam
- D.N.R. State owned land

LAKE BOTTOM SYMBOLS
- P. Peat
- Mk. Muck
- C. Clay
- M. Marl
- Sd. Sand
- St. Silt
- Gr. Gravel
- R. Rubble
- Bc Bedrock
- Boulders
- Stumps & Snags
- Rock danger to navigation
- Submergent vegetation
- Emergent vegetation
- Floating vegetation
- Brush shelters

300' 0 300' 600' 900' 1200'
SCALE

◇ Access ◈ Access with Parking ◆ Boat Livery

Drawn by: T. Ginder
Field work by: C. Busch, G. Lund, & L. Sather

| SPECIES OF FISH | Abundant | Common | Present |
|---|---|---|---|
| Muskie | | X | |
| N. Pike | | | |
| Walleye | | X | |
| L.M. Bass | | | X |
| S.M. Bass | | | |
| Panfish | | X | |
| Trout | | | |
| | | | |

WATER AREA 153.8 ACRES
UNDER 3 FT. 8 %
OVER 20 FT. 0 %
MAX. DEPTH 13 FEET.
TOTAL ALK. 22 P.P.M.
VOLUME 1113.3 ACRE FT.
SHORELINE 1.95 MILES
WITH ISLAND 2.06 MILES

# Appendix 2.

# Dissolved Oxygen, Temperature, Secchi and Conductivity Data

## Dowling Temp Profiles -Deep Hole 96/97

| Depth | 5/19/96 | 6/9/96 | 6/22/96 | 7/14/96 | 7/30/96 | 8/12/96 | 8/25/96 | 9/5/96 | 9/20/96 | 10/7/96 | 10/28/96 | 11/8/96 | 12/1/96 | 12/29/96 | 1/25/97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | 14.6 | 20.4 | 19.7 | 21.9 | 23.6 | 24.8 | 23.5 | 19.9 | 16.1 | 10.9 | 7.8 | 5.9 | 0.3 | | |
| 1 | 14.5 | 20.3 | 19.2 | 21.4 | 23.4 | 24.5 | 22.9 | 19.8 | 16.1 | 10.8 | 7.8 | 5.9 | 2.4 | 0.6 | 0 |
| 2 | 14.5 | 18.1 | 18.2 | 20.3 | 21.6 | 23.1 | 22.5 | 19.7 | 16.1 | 10.8 | 7.7 | 5.6 | 3.1 | 3.6 | 1 |
| 3 | 14.5 | 16 | 16.8 | 20 | 20.9 | 23 | 22.3 | 19.5 | 16.2 | 10.6 | 7.8 | 5.4 | 4.1 | 4.4 | 2.5 |
| 3.5 | 14.4 | | | 19.5 | | | | 19.3 | | | | 4.9 | | | 2.5 |
| **Secchi** | 0.96 | 1.41 | 1.25 | 1.2 | 1.35 | 1.09 | 0.81 | 1.23 | 1.54 | 1.73 | 1.85 | 1.76 | 1.56 | | |

## Dowling Dissolved Oxygen Profiles- Deep Hole 96/97

| Depth | 5/19/96 | 6/9/96 | 6/22/96 | 7/14/96 | 7/30/96 | 8/12/96 | 8/25/96 | 9/5/96 | 9/20/96 | 10/7/96 | 10/28/96 | 11/8/96 | 12/1/96 | 12/29/96 | 1/25/97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | 11.31 | 10.47 | 8.4 | 7.64 | 8.73 | 8.55 | 8.34 | 8.62 | 7.52 | 9.87 | 10.78 | 11.98 | 13.29 | 6.8 | 3.25 |
| 1 | 11.21 | 10.41 | 8.35 | 7.58 | 7.71 | 8.41 | 8.27 | 8.54 | 7.61 | 9.87 | 10.57 | 11.8 | 15.89 | 7.7 | 5.3 |
| 2 | 11.01 | 10.59 | 7.74 | 7.39 | 7.39 | 7.64 | 7.86 | 8.49 | 7.79 | 9.68 | 10.76 | 11.82 | 13.31 | 7.7 | 4.54 |
| 3 | 11.05 | 8.76 | 4.3 | 4.78 | 4.47 | 7.53 | 7.1 | 8.01 | 7.99 | 9.65 | 10.65 | 11.8 | 10.4 | | 2.01 |
| 3.5 | 11.01 | | | 4.47 | | | | 7.89 | | | | 10.4 | | | |

## Dowling Conductivity Profiles - Deep Hole 96/97

| Depth | 5/19/96 | 6/9/96 | 6/22/96 | 7/14/96 | 7/30/96 | 8/12/96 | 8/25/96 | 9/5/96 | 9/20/96 | 10/7/96 | 10/28/96 | 11/8/96 | 12/1/96 | 12/29/96 | 1/25/97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | 30 | 31 | 100 | 47 | 52 | 50 | 150 | 47 | 40 | 42 | 31 | 28 | 19 | 10 | 20 |
| 1 | 30 | | 110 | 47 | 52 | 50 | 150 | 47 | 41 | 42 | 31 | 28 | 25 | 10 | 20 |
| 2 | 30 | | 115 | 49 | 52 | 50 | 150 | 47 | 41 | 41 | 31 | 28 | 31 | 10 | 20 |
| 3 | 30 | | 200 | 49 | 52 | 52 | 155 | 47 | 41 | 43 | 31 | 28 | 39 | 10 | 20 |
| 3.5 | 35 | 35 | | 51 | | 52 | 155 | 53 | | | | 29 | | | |

## Amnicon Temp Profiles- Deep Hole 96/97

| Depth | 5/19/96 | 6/9/96 | 6/22/96 | 7/14/96 | 7/30/96 | 8/12/96 | 8/25/96 | 9/5/96 | 9/20/96 | 10/7/96 | 10/28/96 | 11/8/96 | 12/1/96 | 12/29/96 | 1/25/97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | 14 | 19.3 | 18.2 | 20.2 | 21.6 | 24 | 23.3 | 21.5 | 16.7 | 12.6 | 7.9 | 5.3 | 1.5 | | |
| 1 | 13.9 | 18.6 | 18.6 | 20.2 | 21.6 | 23.9 | 22.5 | 20.6 | 16.7 | 12.6 | 7.9 | 5.3 | 2 | 2.7 | 1.9 |
| 2 | 13.9 | 16.8 | 18.1 | 20.2 | 21.4 | 23.7 | 22.4 | 20.4 | 16.6 | 12.6 | 7.9 | 5.4 | 2.3 | 2.8 | 3.3 |
| 3 | 13.7 | 16.2 | 17.9 | 20.2 | 21.2 | 23 | 22.3 | 20.4 | 16.5 | 12.1 | 7.9 | 5.2 | 2.7 | 3.4 | 3.8 |
| 4 | 13.6 | 15.7 | 16.9 | 20.2 | 20.6 | 22.8 | 22.3 | 19.9 | 16.6 | 12.1 | 7.9 | 5 | 3.3 | 4.2 | 4.6 |
| 5 | 13.4 | 15.6 | 16 | 19.3 | 19.6 | 21.4 | 22.2 | 19.9 | 16.4 | 11.9 | 7.9 | 4.8 | 3.5 | 4.5 | 4.8 |
| 6 | 12.7 | 15.6 | 15.4 | 16.5 | 17.4 | 18.9 | 22.2 | 19.8 | 16.4 | 11.9 | 7.9 | 4.8 | 3.9 | 4.8 | 5 |
| 7 | 12.2 | 15.4 | 15 | 15.8 | 16.1 | 18.3 | 19.7 | 16.9 | 16.4 | 10.8 | 7.9 | 4.9 | 4.1 | 4.9 | 5.1 |
| 7.5 | 12 | | | | | | 16.8 | | | 10.6 | | 4.9 | | 4.9 | 5.3 |
| **Secchi** | 1.22 | 2.21 | 2.05 | 1.81 | 2.03 | 1.76 | 1.52 | 1.93 | 1.87 | 2.01 | 2.28 | 2.1 | 2 | | |

## Amnicon Dissolved Oxygen- Deep Hole 96/97

| Depth | 5/19/96 | 6/9/96 | 6/22/96 | 7/14/96 | 7/30/96 | 8/12/96 | 8/25/96 | 9/5/96 | 9/20/96 | 10/7/96 | 10/28/96 | 11/8/96 | 12/1/96 | 12/29/96 | 1/25/97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | 10.71 | 10.64 | 8.69 | 10.22 | 9.87 | 9.05 | 8.24 | 8.45 | 8.68 | 9.65 | 10.84 | 11.96 | 16.9 | | |
| 1 | 10.72 | 10.74 | 8.63 | 5.09 | 6.73 | 8.94 | 8.14 | 8.43 | 8.64 | 9.63 | 10.98 | 11.96 | 16.65 | 21 | 21 |
| 2 | 10.62 | 10.69 | 8.68 | 4.46 | 6.21 | 8.87 | 7.9 | 8.1 | 8 | 9.59 | 10.91 | 11.94 | 17.53 | 21 | 21 |
| 3 | 10.7 | 9.84 | 8.45 | 3.99 | 5.43 | 8.33 | 7.69 | 8.1 | 8.15 | 9.58 | 10.93 | 11.92 | 18.59 | 21 | 13.3 |
| 4 | 10.82 | 8.45 | 6.17 | 3.65 | 4.12 | 7.83 | 7.71 | 7.89 | 8 | 9.56 | 10.89 | 11.95 | 19.15 | 13.3 | 5.39 |
| 5 | 10.74 | 8.19 | 3.93 | 2.78 | 3.78 | 4.48 | 7.55 | 7.67 | 7.8 | 9.48 | 10.94 | 11.89 | 21 | 11.3 | 1.77 |
| 6 | 10.51 | 8.25 | 1.81 | 1.72 | 1.36 | 0.28 | 7.34 | 7.24 | 7.76 | 9.54 | 10.93 | 11.9 | 21 | 5.7 | 1.73 |
| 7 | 10.21 | 7.11 | 1.11 | 0.91 | 0.92 | 0.24 | 0.35 | 5.63 | 8.1 | 9.5 | 10.1 | 11.88 | 21 | 4.4 | 1.04 |
| 7.5 | 10.11 | | | | | | 0.01 | | | 9.1 | | 11.5 | | 1.3 | 0.82 |

## Amnicon Conductivity - Deep Hole 96/97

| Depth | 5/19/96 | 6/9/96 | 6/22/96 | 7/14/96 | 7/30/96 | 8/12/96 | 8/25/96 | 9/5/96 | 9/20/96 | 10/7/96 | 10/28/96 | 11/8/96 | 12/1/96 | 12/29/96 | 1/25/97 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Surface | 32 | 37.4 | 60 | 49 | 54 | 63 | 65 | 61 | 50 | 48 | 42 | 38 | 29 | 10 | 20 |
| 1 | 32 | | 60 | 49 | 54 | 63 | 65 | 61 | 50 | 48 | 39 | 38 | 40 | 10 | 20 |
| 2 | 32 | | 60 | 50 | 54 | 63 | 65 | 61 | 50 | 48 | 40 | 38 | 41 | 10 | 20 |
| 3 | 32 | | 60 | 50 | 54 | 63 | 65 | 61 | 52 | 48 | 41 | 38 | 41 | 10 | 20 |
| 4 | 32 | | 60 | 50 | 59 | 63 | 65 | 68 | 52 | 48 | 42 | 38 | 45 | 50 | 20 |
| 5 | 32 | | 60 | 50 | 59 | 63 | 65 | 68 | 53 | 50 | 42 | 41 | 48 | 55 | 20 |
| 6 | 36 | | 65 | 50 | 59 | 70 | 70 | 68 | 52 | 50 | 42 | 41 | 50 | 60 | 20 |
| 7 | 38 | 45.3 | 70 | 50 | 59 | 70 | 95 | 73 | 52 | 50 | 42 | 41 | 51 | 60 | 30 |
| 7.5 | 38 | | | | | | 105 | | | 52 | | 41 | | | |