FOLLOW-UP LIMNOLOGICAL SURVEY OF NORTH LAKE, SUMMER 1994 AND A COMPARISON WITH 1988 AND 1992 DATA

Previous studies performed:

23 October 1988 and 10 July, 1992

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INTRODUCTION

This study was commissioned by Bruce Gaffney of the North Lake Association to address the question of documenting the response of North Lake to the changeover from septic systems to a sewer system. Limnological tests were conducted to determine the current water quality status of the lake and compare it with data collected previously in 1988 and 1992.

We gratefully acknowledge Bruce Gaffney for his assistance in locating the deepest spot in the lake and his help with the sampling.

METHODS

Our study involves physical, chemical, and biological measurements and observations by professional aquatic biologists who have conducted lake management studies since 1972. We focused on the plant problems for our North Lake studies. We use specialized samplers and equipment designed to thoroughly examine all components of an aquatic ecosystem. Shallow water, deep water, sediments, animal and plant life as well as inlet and outlet streams are intensively sampled and analyzed at several key stations (sites on the lake). Our SCUBA divers examine aquatic plants, sediments, and fish and assist in some other data collections. Some samples are analyzed in the field, while the balance are transported to our laboratory for measurements and/or identification of organisms found in samples.

After the field study, we compile, analyze, summarize, and interpret data. We utilize a comprehensive library of limnological studies, and review all the latest management practices in constructing a management plan. All methods used are standard limnological procedures, and most chemical analyses are according to Standard Methods for the Examination of Water and Wastewater.

STATION LOCATIONS

During any study we choose a number of places (stations) where we do our sampling for each of the desired parameters. We strive to have a station in any unusual or important place, such as inlet and outlet streams, as well as in representative areas in the lake proper. One of these areas is always the deepest part of the lake. Here we check on the degree of thermal and chemical stratification, which is extremely important in characterizing the stage of eutrophication (nutrient enrichment), invertebrates present, and possible threats to fish due to production of toxic substances due to decomposition of the bottom sediments. The number and location of these stations for this study are noted in that section.

PHYSICAL PARAMETERS

Depth

Depth is measured in several areas with a sonic depth finder or a marked sounding line.

Acreage

Acreage figures, when desired, are derived from maps, by triangulation, and/or estimation. The percentage of lake surface area in shallow water (less than 10 feet) is an important factor. This zone (known as the littoral zone) is where light can penetrate with enough intensity to support rooted aquatic plants. Natural lakes usually have littoral zones around their perimeters. Man-made lakes and some reservoirs often have extensive areas of zone.

Sediments

Bottom accumulations give good histories of the lake. The depth, degree of compaction, and actual makeup of the sediments reveal much about the past. An Ekman grab or dredge sampler is used to sample bottom sediments for examination. It is lowered to the bottom, tripped with a weight , and it "grabs" a 1 square foot sample of the bottom. Artificial lakes often fill in more rapidly than natural lakes because disruption of natural drainage systems occurs when these lakes are built. Sediments are either organic (remains of plants and animals produced in the lake or washed in) or inorganic (non-living materials from wave erosion or erosion and run-off from the watershed).

Light Penetration

The clarity of the water in a lake determines how far sunlight can penetrate. This in turn has a basic relationship to the production of living phytoplankton (minute plants called algae) which are basic producers in the lake and the foundation of the food chain. We measure light penetration with a small circular black and white Secchi disc attached to a calibrated line. The depth at which this disc just disappears (amount of water transparency) will vary between lakes and in the same lake during different seasons, depending on degree of water clarity. This reference depth can be checked periodically and can reflect the presence of plankton blooms and turbidity caused by urban run-off, etc.

Temperature

This is a physical parameter but will be discussed in the chemistry section with dissolved oxygen. Thermal stratification is a critical process in lakes which helps control the production of algae, generation of various substances from the bottom, and dissolved oxygen depletion rates.

Stream Flows from Inlets and Outlets

Estimation of flows in and out of a lake give us information about ground water inputs, inputs of nutrients and toxic substances, and amount of water moving through the ecosystem. When tied to the chemical analyses described earlier, nutrient inputs and outputs can be calculated and amount of impact of these inputs evaluated.

CHEMICAL PARAMETERS

Water chemistry parameters are extremely useful measurements and can reveal considerable information about the type of lake and how nutrients are fluxing through the system. They are important in classifying lakes and can give valuable information about the kind of organisms that can be expected to exist under a certain chemical regime. All chemical parameters are a measure of a certain ion or ion complex in water. The most important elements--carbon (C), hydrogen (H), and oxygen (O) are the basic units that comprise all life, so their importance is readily obvious. Other elements like phosphorus (P) and nitrogen (N) are extremely important because they are significant links in proteins and RNA/DNA chains. Since the latter two (P and N) are very important plant nutrients, and since phosphorus has been shown to be critical and often times a limiting nutrient in some systems, great attention is given to these two variables. Other micro-nutrients such as boron, silicon, sulfur, and vitamins can also be limiting under special circumstances. However, in most cases, phosphorus turns out to be the most important nutrient.

Temperature Stratification

Temperature governs the rate of biological processes. A series of temperature measurements from the surface to the bottom in a lake (temperature profile) is very useful in detecting stratification patterns. Stratification in early summer develops because the warm sun heats the surface layers of a lake. This water becomes less dense due to its heating, and "floats" on the colder, more dense waters below. Three layers of water are thus set up. The surface warm waters are called the epilimnion, the middle zone of rapid transition in temperatures is called the thermocline, and the cold bottom waters, usually around 39 F (temperature of maximum density), are termed the hypolimnion. As summer progresses, the lowest cold layer of water (hypolimnion) becomes more and more isolated from the upper layers because it is colder and more dense than surface waters.

When cooler weather returns in the fall, the warm upper waters (epilimnion) cool to about 39 F, and because water at this temperature is the most dense (heaviest), it begins to sink slowly to the bottom. This causes the lake to "turnover" or mix, and the temperature becomes a uniform 39 F top to bottom. Other chemical variables, such as dissolved oxygen, ammonia, etc. are also uniformly distributed throughout the lake.

As winter approaches, surface water cools even more. Because water is most dense at 39 F, the deep portions of the lake "fill" with this "heavy water". Water colder than 39 F is actually lighter and floats on the more dense water below, until it freezes at 32 F and seals the lake. During winter decomposition on the bottom can warm bottom temperatures slightly.

In spring when the ice melts and surface water warms from 32 to 39 F, seasonal winds will mix the lake again (spring overturn), thus completing the yearly cycle. This represents a typical cycle, and many variations can exist, depending on the lake shape, size, depth, and location. Summer stratification is usually the most critical period in the cycle, since the hypolimnion may go anoxic (without oxygen--discussed next), we always try to schedule our sampling during this period of the year. Another critical time exists during late winter as oxygen can be depleted from the entire water column in certain lakes under conditions of prolonged snow cover.

Dissolved Oxygen

This dissolved gas is one of the most significant chemical substances in natural waters. It regulates the activity of the living aquatic community and serves as an indicator of lake conditions. Dissolved oxygen is measured using the Winkler method with the azide modification. Fixed samples are titrated with PAO (phenol arsene oxide) and results are expressed in mg/L (ppm) of oxygen, which can range normally from 0 to about 14 mg/L. Water samples for this and all other chemical determinations are collected using a device called a Kemmerer water sampler, which can be lowered to any desired depth and like the Ekman grab sampler, tripped using a messenger (weight) on a calibrated line. The messenger causes the cylinder to seal and the desired water sample is then removed after the Kemmerer is brought to the surface. Most oxygen in water is the result of the photosynthetic activities of plants, the algae and aquatic macrophytes. Some enters water through diffusion from air. Animals use this oxygen while giving off carbon dioxide during respiration. The interrelationships between these two communities determine the amount of productivity that occurs and the degree of eutrophication (lake aging) that exists.

A series of dissolved oxygen determinations can tell us a great deal about a lake, especially in summer. In many lakes in this area of Michigan, a summer stratification or stagnation period occurs (See previous thermal stratification discussion). This layering causes isolation of three water masses because of temperature-density relationships already discussed. In the spring turnover period dissolved oxygen concentrations are at saturation values from top to bottom. However, in these lakes by July or August some or all of the dissolved oxygen in the bottom layer is lost (used up by bacteria) to the decomposition process occurring in the bottom sediments. The richer the lake, the more sediment produced and the more oxygen used up. Since there is no way for oxygen to get down to these layers (there is not enough light for algae to photosynthesize), the hypolimnion becomes devoid of oxygen in rich lakes. In non-fertile (Oligotrophic) lakes there is very little decomposition, and therefore little or no dissolved oxygen depletion. Lack of oxygen in the lower waters (hypolimnion) prevents fish from living here and also changes basic chemical reactions in and near the sediment layer (from aerobic to anaerobic).

Stratification does not occur in all lakes. Shallow lakes are often well mixed throughout the year because of wind action. Some lakes or reservoirs have large flow-through so stratification never gets established.

Stratified lakes will mix in the fall because of cooler weather, and the dissolved oxygen content in the entire water column will be replenished. During winter the oxygen may again be depleted near the bottom by decomposition processes. As noted previously, winterkill of fish results when this condition is caused by early snows and a long period of ice cover when little sunlight can penetrate into the lake water. Thus no oxygen can be produced, and if the lake is severely eutrophic, so much decomposition occurs that all the dissolved oxygen in the lake is depleted.

In spring, with the melting of ice, oxygen is again injected into the hypolimnion during this mixing or "turnover" period. Summer again repeats the process of stratification and bottom depletion of dissolved oxygen.

One other aspect of dissolved oxygen (DO) cycles concerns the diel or 24-hour cycle. During the day in summer, plants photosynthesize and produce oxygen, while at night they join the animals in respiring (creating CO_2) and using up oxygen. This creates a diel cycle of high dissolved oxygen levels during the day and low levels at night. These dissolved oxygen sags have resulted in fish kills in lakes, particularly near large aquatic macrophyte beds on some of the hottest days of the year.

pH

The pH of most lakes in this area range from about 6 to 9. The pH value (measure of the acid or alkaline nature of water) is governed by the concentration of H (hydrogen) ions which are affected by the carbonate-bicarbonate buffer system, and the dissociation of carbonic acid (H2CO3) into H + ions and bicarbonate. During a daily cycle, pH varies as aquatic plants and algae utilize CO2 from the carbonate-bicarbonate system. The pH will rise as a result. During evening hours, the pH will drop due to respiratory demands (production of carbon dioxide, which is acidic). This cycle is similar to the dissolved oxygen cycle already discussed and is caused by the same processes. Carbon dioxide causes a rise in pH so that as plants use CO2 during the day in photosynthesis there is a drop in CO2 concentration and a rise in pH values, sometimes far above the normal 7.4 to values approaching 9. During the night, as noted, both plants and animals respire (give off CO2), thus causing a rise in CO2 concentration and a concomitant decrease in pH toward a more acidic condition. We use pH as an indicator of plant activity as discussed above and for detecting any possible input of pollution which would cause deviations from expected values. pH is measured in the field with color comparators and in the laboratory with a Beckman pH meter.

Chlorides

Chlorides are unique in that they are not affected by physical or biological processes and accumulate in a lake, giving a history of past inputs of this substance. Chlorides (Cl-) are transported into lakes from septic tank effluents and urban run-off from road salting and other sources. Chlorides are detected by titration using mercuric nitrate and an indicator. Results are expressed as mg/L as chloride. The effluent from septic tanks is high in chlorides. Dwellings around a lake having septic tanks contribute to the chloride content of the lake. Depending upon flow-through, chlorides may accumulate in concentrations considerably higher than in natural ground water. Likewise, urban run-off can transport chlorides from road salting operations and also bring in nutrients. The chloride "tag" is a simple way to detect possible nutrient additions and septic tank contamination. Ground water in this area averages 10-20 mg/L chlorides. Values above this are indicative of possible pollution.

Phosphorus

This element, as noted, is an important plant nutrient which in most aquatic situations is the limiting factor in plant growth. Thus if this nutrient can be controlled, many of the undesirable side effects of eutrophication (dense macrophyte growth and algae blooms) can be avoided. The addition of small amounts of phosphorus (P) can trigger these massive plant growths. Usually the other necessary elements (carbon, nitrogen, light, trace elements, etc.) are present in quantities sufficient to allow these excessive growths. Phosphorus usually is limiting (occasionally carbon or nitrogen may be limiting). Two forms of phosphorus are usually measured. Total phosphorus is the total amount of P in the sample expressed as mg/L or ppm as P, and soluble P or Ortho P is that phosphorus which is dissolved in the water and "available" to plants for uptake and growth. Both are valuable parameters useful in judging eutrophication problems.

Nitrogen

There are various forms of the plant nutrient nitrogen, which are measured in the laboratory using complicated methods. The most reduced form of nitrogen, ammonia (NH_3) is usually formed in the sediments in the absence of dissolved oxygen and from the breakdown of proteins (organic matter). Thus high concentrations are sometimes found on or near the bottom under stratified anoxic conditions. Ammonia is reported as mg/L as N and is toxic in high concentrations to fish and other sensitive invertebrates, particularly under high pHs. With turnover in the spring most ammonia is converted to nitrates ($NO_3^=$) when exposed to the oxidizing effects of oxygen. Nitrite (NO_2^-) is a brief form intermediate between ammonia and nitrates, which is sometimes measured. Nitrites are rapidly converted to nitrates when adequate dissolved oxygen is present. Nitrate is the commonly measured nutrient in limnological studies and gives a good indication of the amount of this element available for plant growth. It, with Total P, are useful parameters to measure in streams entering lakes to get an idea of the amount of nutrient input. Profiles in the deepest part of the lake can give important information about succession of algae species, which usually proceeds from diatoms, to green algae to blue-green algae. Blue-green algae (an undesirable species) can fix their own nitrogen (some members) and thus out-compete more desirable forms, when phosphorus becomes scarce in late summer.

RESULTS

WATERSHED

North Lake is located in Washtenaw County (T1S R3-4E S13,16) and is 220 acres. The watershed of North Lake is mostly wooded with some agricultural activities. There are some many houses around the perimeter of the lake, allowing a considerable amount of access, with more development occurring since our previous visits. There are therefore many potential threats to the integrity of the lake from runoff. This runoff can be derived from pet droppings, lawn and garden fertilization, washing of cars in the driveway, eaves trough runoff, antifreeze, and similar sources. It cannot be stressed enough that each individual resident on the lake must take responsibility for the water quality of the runoff that traverses their piece of terrestrial habitat that is so intimate with the lake.

The local watershed, including those houses immediately on the lake, is very important also. Lawn fertilization and disturbance of the lake surface for new developments, etc., cause additional nutrients to be exported to the lake, and further speed the enrichment process. Lake front property owners should be made aware that each resident has responsibility for controlling and reducing nutrient and sediment inputs to North Lake, and that individuals do count in this battle against cultural eutrophication. Things that can be done to inhibit entry of undesirable and deleterious substances into the lake are planting greenbelts along the lake edge, reducing erosion where ever it occurs, reducing the use of fertilizers for lawns , cutting down on road salting operations, not feeding the geese or ducks, no leaf burning near the lake, prevention of leaves and other organic matter from entering the lake, no effluent pipes or drains which run directly into the lake, care in household use of such substances as fertilizers, detergents to wash cars and boats, pesticides, cleaners like ammonia, and vehicle fluids, such as oil, gas, and antifreeze, and elimination of willow trees around the lake which can add leaves and branches to an already over fertilized lake.

STATION LOCATION

We established one station in the deepest part of North Lake for determining the current status of water quality in the lake during summer 1994. This was the same station we used in our 1988 and 1992 studies to promote comparison among parameters.

Light Penetration

The secchi disc reading at station A was 12 feet during 10 July 1992, while during 19 August 1994 it was reduced somewhat to 9 feet 10 inches. Both readings are reasonable and confirm that the lake was not undergoing severe algal blooms.

Temperature

Water temperature is intimately associated with the dissolved oxygen profiles in a lake. North Lake was stratified in our 1992 studies, but showed very little stratification in 1988 when we did our studies, which is to be expected since stratification is broken up in the fall (Table 1). Water temperatures were consistently 20-21 C at the surface in 1992. Bottom temperatures were 7.0 C and a typical pattern was observed. During 1994, temperatures were 23.4 C in the surface waters then declined in the thermocline to 17.2 and it was 14.5 C on the bottom, which was considerably warmer than what was observed during 1992. We attribute this difference to the later date of measurements in 1994, which allowed additional heat input from bottom sediment decompositional processes. It also affected dissolved oxygen concentrations as well.

CHEMICAL PARAMETERS

Dissolved Oxygen

The dissolved oxygen in North Lake was not stratified in 1988 as expected (fall data), while in 1992 and 1994, it was stratified and followed the same pattern as the temperature (Table 1). In 1992, there was reduced dissolved oxygen on the bottom of the lake, but it was not anoxic (no dissolved oxygen). This is a positive feature of North Lake, because it does two things for the lake. First, it allows fish access to bottom waters, which is necessary for northern pike, and it allows fish access to food supplies derived from the bottom sediments. However, the levels measured are too low for prolonged residence by fish in these strata. At around 2-3 mg/L, coolwater fish species become stressed, so they will only be able to descend into these depths for short term bouts. Second, dissolved oxygen on the bottom prevents phosphorus from re-entering the water column, which occurs during anoxic conditions. Phosphorus is a plant nutrient which fuels algal and macrophyte growth. In 1994, there was no dissolved oxygen in the bottom waters, which was also verified by several other chemical measures for the lake. Since the previous data were collected during July, we are of the opinion, that conditions in 1994 were probably similar to that which we measured in 1992, especially July, i.e., the lake was stratified and that there was probably low levels of dissolved oxygen present in the bottom during July 1994.

The conclusions are therefore these: first, the lack of dissolved oxygen on the bottom means that during August, there is a substantial part of the lake (depths below about 10 m - 33 feet) that is not suitable habitat for fish. It also means that there is phosphorous regeneration from the sediments in the areas of the bottom where there is no dissolved oxygen. This phosphorous is then re-suspended into the water column in the spring, to fuel plant and algal growth in the spring and summer. Second, there has not been much change in the dissolved oxygen concentrations on the bottom of North Lake from 1992 to 1994, as best we can judge (since data were collected in different months, it negates a sound comparison). We wish to use the pattern of the dissolved oxygen profile as an indicator of change after sewers are in place in the lake. Since we have documented a fairly consistent pattern of stratification, it sets the stage for comparisons in later years. Should we see no depletion of dissolved oxygen from the bottom waters in later years, it would be good evidence that curtailment of septic tank leakage into the lake was a positive step to take.

Table 1. Some physical and limnological parameters measured 23 August 1988 10 July 1992, and 16 August 1994 on North Lake, Oakland County, Michigan. Units: mg/l = milligrams per liter or parts per million; SRP = soluble reactive phosphorus; Cond . = conductivity, units are micromhos (umhos); ND = non detectable. Surf=surface, Bott=bottom, Mid=mid-depth. Depth in meters. Alkalinity and hardness in mg/L as CaCO3, temperature in Centigrade.

Station-Depth		pH	Cond.	Secchi Disc (ft)	Alkalinity	Hardness
				10 July 1992		
A	Surf- 0 M	7.95	341	12		
	Mid - 7 M	7.04	373			
	Bott-14 M	6.94	389			
				19 August 1994		
A	Surf- 0 M	8.40	383	9.8	96	112
	3 M	8.51	387		94	114
	6 M	7.85	384		100	118
	9 M	7.91	437		126	142
	12 M	7.75	449		140	152
	14 M	7.68	448		142	158

Table 1. Continued.

Station/Depth	Ammonia (mg/L)	Nitrate (mg/L)	SRP (mg/L)	Silica (mg/L)	Chlorides (mg/L)
		23 October 1988			
A-SURF 0 M	0.057	0.008	0.003	0.11	42.17
A-MID 6 M	0.058	0.003	0.003	0.01	42.13
A-BOT 12 M	0.097	0.023	0.006	0.40	42.46
		10 July 1992			
A-SURF 0 M	0.016	0	0.001	no data	42.1
A-MID 6 M	0.024	0	0.001	no data	41.7
A-MID 13 M	0.339	0	0.001	no data	40.8
		16 August 1994			
A-SURF 0 M	0.002	<0.001	0.002	2.12	46.2
3 M	0.004	<0.001	0.003	2.21	46.1
A-MID 6 M	0.004	<0.001	0.002	1.58	45.4
9 M	0.290	<0.001	0.003	1.65	45.7
12 M	0.758	<0.001	0.002	2.12	45.4
A-BOT 14 M	0.971	<0.001	0.003	2.76	45.4

Table 1. Continued.

Sta	Depth	Temp.	Diss. Oxygen	Depth	Temp	Diss. Oxygen	Depth	Temp	Oxygen
	23 October 1988			10 July 1992			16 August 1994		
A	0	11.0	10.8	0	21.0	9.0	0	23.4	7.3
A	1			1	21.2	9.0	1		
A	2			2	21.0	9.0	2		
A	3			3	21.0	9.0	3	23.4	8.0
A	4			4	20.5	8.0	4		
A	5			5	17.0	4.4	5		
A	6	11.0	10.8	6	14.0	2.6	6	21.1	5.8
A	7			7	12.0	2.2	7		
A	8			8	10.0	1.7	8		
A	9			9	8.5	1.3	9	17.2	1.4
A	10			10	7.5	1.2	10		
A	11			11	7.5	1.1	11		
A	12			12	7.2	1.0	12	15.6	0
A	13	10.8	10.8	13	7.0	1.0	13		
							14	14.5	0

pH

The pH (how acid or alkaline water is) data for North Lake, showed a typical pattern of high values in surface waters and a progressive decline in bottom waters in 1992 and 1994 (Table 1). This again is expected as decomposition of sediments on the bottom releases large quantities of carbon dioxide which makes the water acidic.

Chlorides

Chlorides are another key limnological parameter which we will be closely examining for changes related to sewer placement in the lake. Since they can be derived from road salting operations and/or septic tank inflow (chlorides are largely biologically and chemically inactive), any increases that occur indicate inputs of either high quantities of salt into the lake from road salting or septic tank inputs. On the other hand, if there is a decline in or a consistent concentration of chlorides in North Lake, one might conclude that the switch to sewers diverted chlorides, and accompanying nutrients away from the lake. Chloride data from in lake stations were around 42 mg/L during 1988, 41-42 during 1992, but then increased substantially to 45-46 mg/L during 1994 (Table 1). First, 45 mg/L of chlorides is not alarming, but it certainly is not clean ground water which usually has around 2-4 mg/L of chlorides. These levels indicate a history of input of salt into the lake, from either of the two sources noted above. What we are concerned about is not the chlorides, but what they indicate for the lake. Since chlorides enter the lake from the groundwater via septic fields or from runoff which carries road salt into the lake, it can be seen that what accompanies chlorides, the nutrients, were also probably high, and part of the reason why aquatic plants flourish so well in the lake. Second, there was no change in chloride concentrations from 1988 to 1992, but then a substantial increase of almost 4 mg/L from 1992 to 1994. This is somewhat surprising and indicates some recent changes in the inputs of chlorides to North Lake in the past 2 years. There was no change in the 5 years from 1988 to 1992, then a 4 mg/L increase from 1992 to 1994. It does establish a trend and additional data in years to come will help interpret what types of changes may be attributed to the recent upsurge in this chemical in the lake.

Phosphorus

Data on phosphorus at the in-lake stations (A - Table 1) show that soluble reactive phosphorus (SRP) was very low, from 0.001 to 0.006 mg/L on both dates, 1988, 1992, and 1994. Concentrations of 0.03 mg/L are high enough to cause an algal bloom, so all values are well below that. The SRP is low because most of the phosphorus is being taken up by the algae and aquatic plants in the lake.

Nitrates

Nitrate is very important since it is a critical plant nutrient. We found non-detectable levels in North Lake during 1992 and 1994, while during 1988 concentrations ranged from 0.008 at the surface to 0.023 mg/L in bottom waters during October. It appears that like the case with phosphorus, the aquatic plants and algae are taking up large amounts of the nutrients. Therefore, great care should be taken before any wholesale destruction of aquatic plants is completed, since it may shift the flow of nutrients into the algae, which are notoriously difficult to control and aesthetically unpleasing to lake dwellers. We have seen *Chara*, a green alga that looks like an aquatic macrophyte and lives in thick mats on the bottom, perform this same function (taking up nutrients) in other lakes in your area.

Ammonia

Ammonia is also a plant nutrient, but it can be toxic in high concentrations to fish. It is formed by the decomposition of bottom sediments or can enter with runoff through the storm drains. Concentrations in North Lake on 23 October 1992 (Table 1) were low throughout the upper water column (0.01-0.02 mg/L), which is a good sign; however there was a high buildup in bottom waters (0.33 mg/L). A similar pattern was observed in 1994 and even higher concentrations were noted in bottom waters (0.971 mg/L). Again, this is because the samples were taken in August, later in the year, which allowed additional decomposition to occur in the lake bottom and raising the concentration of ammonia. These are not alarmingly high levels, but high enough, in conjunction with the anoxia, to kill any fish which would swim into that area. This ammonia will be distributed throughout the lake next spring at turnover and contribute to plant growth during spring and summer. It is an indication plant decomposition on the bottom of the lake.

Hydrogen Sulfide

Hydrogen sulfide is a toxic substance produced under conditions of no dissolved oxygen from the decomposition of organic matter. We found no hydrogen sulfide on the bottom in 1988 and 1992 which is expected, since there was dissolved oxygen at the bottom of the lake at the in-lake stations. However, during 1994, we measured anoxia on the bottom and a low level of hydrogen sulfide as well - 0.5 mg/L. Again this is confirmatory evidence of the degraded water quality conditions that occur on the bottom of the lake during the late summer anoxic period. Such conditions were not documented during July 1992.

Silica

Silica is an important component of some algae (diatoms). The deep in-lake station showed low levels of silica, from 0.01 to 0.40 mg/L in 1992 (Table 1). In 1994, we found much higher concentrations of silica, since the period of diatom growth (spring) was over, allowing buildup of silica later on in the summer. We usually observe low quantities in surface waters (taken up by algae in the spring) and increasingly higher concentrations on the bottom.

Conductivity

Conductivity is a measure of the ability of water to conduct current and is proportional to the dissolved solutes present. Conductivity was generally at expected levels in the lake proper, around 350-450 umhos from surface to bottom during both 1992-1994 (Table 1) at station A.

CONCLUSIONS

INTRODUCTION

Our attempt in this report was to consolidate all the data collected over 1988, 1992, and 1994 with a view toward establishing a database and pattern of limnological parameters from which future changes in the lake can be determined. These future changes especially include what types of potential improvements might result from building sewers and diverting the flow of nutrients from septic tanks into the sewers. This database is based on the findings we made and of course are heavily biased by the conditions we observed at the time of sampling. The limnological data collected in 1988 were collected because we try to collect such data as part of our work in any lake investigation, so since the work in 1988 was aimed at a macrophyte survey, the data collected in November were not collected at an ideal time, which is during late summer during maximum stratification conditions. During 1992, the data were collected in July, which is not the month of maximum stratification, but does give a good indication of limnological conditions. Therefore, although the data were not collected in the same months, nor were similar data collected over all years, there still are some inferences that can be made from the concentrations observed and the patterns measured during the 3 years noted.

CONSISTENT PATTERNS

The indicator that stood out most among those measured in this study was chlorides. They are important indicators of historical changes and as noted, are bellwethers of nutrient input to a lake. They can also be indicative of road salt runoff into the lake and septic tank leakage. So far the evidence is rather surprising. We saw no change for 5 years (1988 through 1992) then an increase of 4 mg/L from 1992 to 1994. Some additional work needs to be done to identify if any of the road salting patterns changed or whether new developments or a paved road somewhere in the watershed caused the increased salt input. However, if there are no changes, then the septic tank groundwater inflows might be to blame; again changes in additional development in the watershed should be examined. At any rate, these data will act as an important baseline for future changes; the reason for these changes must be evaluated in terms of the other parameters we measured.

The dissolved oxygen profile in a lake is an important criterion we examine to determine how eutrophic or impacted that lake could be. Since the profile we measured on July 1992 was probably not representative of maximum stratification, we intend to use the August 1994 as a baseline to determine if those conditions improve or remain the same after sewers are established around the lake. For example, if the anoxia (no dissolved oxygen on the bottom) we observed in August 1994, remains the same or improves (becomes similar to the conditions we observed in July 1992) then we could conclude, if other climatic factors are not important, that a reduction in the enriched condition of the lake has occurred. However, we should warn that many years may be required before such a response is observed, since the sediments act as a nutrient sink, even if all nutrient inputs to the lake were cut off.

Lastly, there were several other parameters that are important criteria for judging how the lake responds to reduced nutrient additions to the lake. These include hydrogen sulfide, nitrates, ammonia, soluble reactive phosphorus, and the secchi disc reading. In the latter case, we strongly recommend a program of measuring secchi disc transparency weekly during summer be started to provide the type of historical background data required to document changes in the water transparency of the lake.