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**WATER QUALITY ASSESSMENT
OF HORSESHOE LAKE**

by Thomas E. Hill, Ralph L. Evans, and J. Scott Bell

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ABSTRACT

This study was made to assess and define the basic water quality characteristics of Horseshoe Lake, located in the Mississippi River flood plain northeast of East St. Louis, Illinois, and to determine whether or not these characteristics limit certain proposed uses of the lake. Water samples were collected approximately every two weeks from May 25, 1978, to January 23, 1979, and were analyzed with respect to temperature, dissolved oxygen, transparency, alkalinity, pH, ammonia-nitrogen, phosphorus, suspended and dissolved solids, and turbidity. Other determinations were made with respect to metal content, benthic macroinvertebrates, algae, zooplankton, macrophytes, sediment oxygen demand, and nocturnal dissolved oxygen. The findings revealed that the water quality of Horseshoe Lake is governed by three major agents - shallow water depth, algal productivity, and effluent from Granite City Steel Company - and that control measures applied solely to these factors can lead to the enhancement of water quality in the lake. It was determined that the shallowness of the lake waters, compounded by the current management of water levels, produces several adverse effects; that algal densities of bloom proportion existing on most of the water surface of the lake from mid-July to mid-October have a profoundly negative effect on the water quality; and that the effluent from Granite City Steel, while providing certain beneficial influences on the quality of the lake water, poses threats with respect to excessive ammonia-nitrogen concentrations, high chlorine doses, and high potassium levels. The study provides information that will be useful in the decision-making process regarding improvements in water quality and uses of the lake.

INTRODUCTION

Horseshoe Lake, located in Madison County, Illinois, is an oxbow lake occupying a meander scar of the Mississippi River flood plain northeast of East St. Louis, Illinois. The lake is located approximately 2 miles east of the main stem of the Mississippi River. Its location and configuration are shown in figure 1.

The pressing need for recreational areas close to the metropolitan St. Louis-East St. Louis area prompted public recreational development of this lake. Presently, the Illinois Department of Conservation (IDOC) has purchased about one-third of the lake, with plans for further acquisition. Major uses of the lake include flood water retention, assimilation of industrial waste effluent, commercial sand and gravel operation, waterfowl hunting, commercial and recreational fishing, and wildlife observation.

The average depth of the lake is about 3 feet at the overflow pool elevation (4 . 3.8 feet mean sea level), except for a deep hole about 5 . feet deep

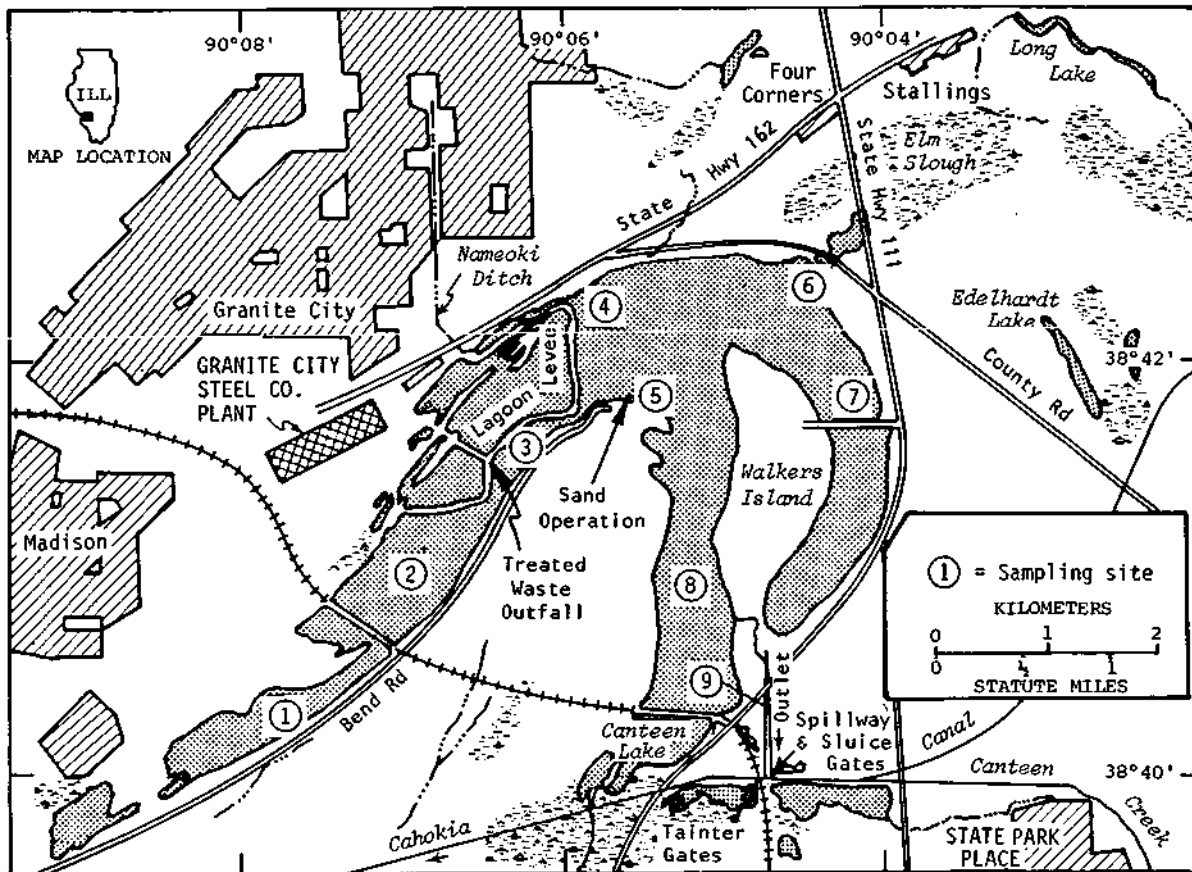


Figure 1. Location and avel layout, Horseshoe Lake

near the sand and gravel operation and a depression in the vicinity of effluent discharges from Granite City Steel (GCS). The typical water surface area at normal pool elevation is about 215 . acres. Under normal conditions, the major sources of flow into the lake are urban runoff through Nameoki Ditch, agricultural runoff through Elm Slouth, and the treated waste effluent from the GCS facilities, amounting to 25 million gallons per day (mgd). During storm events, which are likely to occur about 1 . times per year (Lee, 1978), storm water flows in the Cahokia Canal are diverted into the lake for flood retention purposes. Lake levels can be drawn down below spillway level through a low flow weir arrangement operated by the Metro East Sanitary District. Figure 2 depicts the relative locations of the inflow-outflow structures.

Groundwater

The current hydraulic interchange between the water of the lake and groundwater is low. According to Prickett (1977) an estimated average 1.5 mgd of water leaked from the lake into the aquifer during the extended drought of 1953. During recent years (1973-1974) about 2.5 mgd of groundwater has been added to the lake from the aquifer because of higher groundwater elevations. Increased sedimentation of the lake since the data period for which these cal-

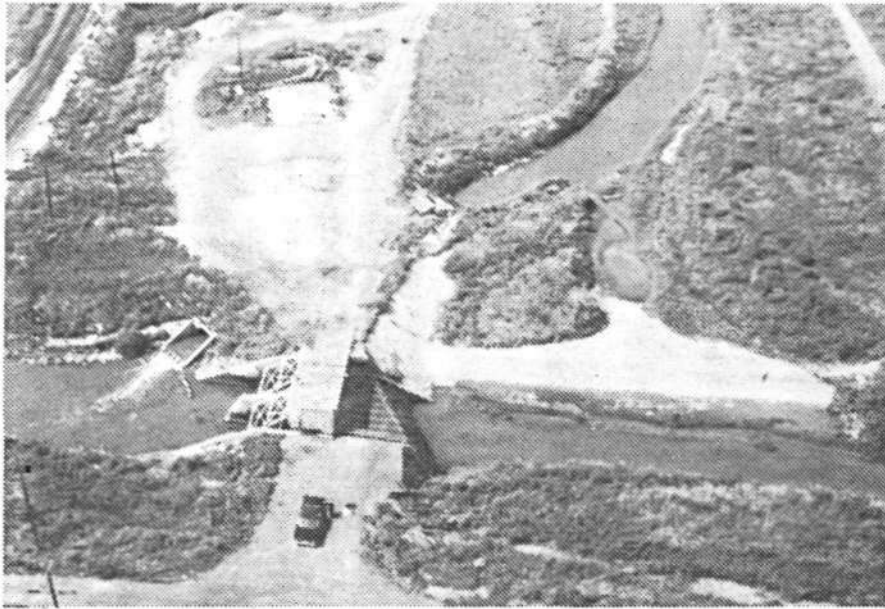


Figure 2. Inflow-outflow structures, Horseshoe Lake

culations were made (1947-1956) has minimized the relative influence of the groundwater,, Groundwater intrusion is not considered a significant factor compared to surface flows.

Granite City Steel

Prior to June 1977 the GCS waste treatment facilities discharged about 68 mgd into Horseshoe Lake. Since June 1977 additions have been made to the treatment facilities for the recycling of about 44 mgd of treated waste from the lagoon systems back to production operations. Existing treatment provides for oil skimming, parallel operation of two lagoons, chlorination, coagulation, sand filtration, and sulfonation. An operation and maintenance inspection of the facilities was performed by the Illinois Environmental Protection Agency (IEPA) during July 1977. Based upon that inspection the IEPA concluded that the facilities are being properly operated and maintained and that all effluent limitations are being met. The National Pollution Discharge Elimination System (NPDES) limits and IEPA effluent standards are shown in table 1.

Fish Population

The lake sustains a commercial fishery consisting mainly of carp, buffalo, channel catfish, and freshwater drum. Covich (1975) reports that annual yields varied from 12,000 to 88,700 pounds from 1957 to 1973. Marbut (1978) suggests that the average annual yield between 1974 and 1977 was 16,000 pounds.

The sport fishery is marginal, consisting of about 10 percent of the fish population (Marbut, 1974). In the past, largemouth bass and bluegill were

Table 1. NPDES Limits and IEPA Effluent Standards
 (Concentrations in milligrams per liter unless otherwise indicated)

| <i>Parameter</i> | <i>Illinois effluent standards</i> | <i>NPDES limits (daily maximum)</i> |
|---------------------------|--|---|
| pH (units) | 5-10 | 6-9 |
| Dissolved solids | 750+background | |
| Suspended solids | 15 | 30 |
| Biochemical oxygen demand | | 25 |
| Cyanide | 0.10* | 0.025 |
| Phenol | 0.3 | |
| Fluoride | 2.5 | |
| Total cadmium | 0.15 | |
| Trivalent chromium | 1.0 | |
| Hexavalent chromium | 0.3 | |
| Total copper | 1.0 | |
| Dissolved iron | 0.5 | |
| Total iron | 2.0 | 2.0 |
| Total lead | 0.1 | |
| Total manganese | 1.0 | |
| Total mercury | 0.0005 | |
| Total nickel | 1.0 | |
| Total zinc | 1.0 | 1.0 |
| Oil and grease | | 10 |
| Fecal coliform | | 400/100ml |

* Amended as of September 15, 1978

significant in the sport fishery, but a population census conducted in July 1977 by IDOC indicates that the reproduction and growth rates of largemouth bass and bluegill are so poor that the species are no longer considered a fishery. Currently the principal sport fish is channel catfish.

Fourteen fish kills have been reported since 1959. Of the last six episodes, five occurred during December, January, or February. In terms of monetary value, the most recent fish kills, which occurred in February and December of 1977, were the most devastating. The causes for these two fish kills have not been determined.

According to a report of the IDOC (Marbut, 1977) the February incident occurred on February 8, 1977, but because of late notification an investigation was not performed until the 18th. Dead fish, a reddish discoloration of the water, and sediments were observed in part of the lake. An estimated 90,000 fish were killed, of which 43 percent were shad, 33 percent were catfish, 8 percent were carp, 5 percent were minnows, 3 percent were sunfish, and 8 percent were other kinds of fish. These fish were estimated to be worth \$12,600. Results of water samples taken by the IEPA on March 2, 1977, showed: dissolved oxygen 12 parts per million (ppm), pH 7.2, alkalinity 128 ppm, and water temperature 4°C.

Marbut (1977) also reported on the fish kill that occurred about December 12, 1977. Dead fish were first noticed by a lake resident three days previous to the investigative date of December 15. Ice covered much of the lake and the water appeared normal in color. Dead fish were observed under the ice, and distressed fish were seen flipping around or hanging perpendicularly in the water. Dead fish could be seen along the shore near Bend Road, but a large number of dead fish were observed near the Quality Sand Company operation. An estimated 80,000 fish were killed, of which 90 percent were shad, 5 percent were catfish, 2 percent were sunfish, and 3 percent were other kinds of fish. These fish were estimated to be worth \$10,000. The IEPA collected and analyzed three water samples taken on December 16, 1977. The results are shown in table 2.

Six species of fish collected February 27, 1976, from Horseshoe Lake were tested for the IDOC by the Illinois Department of Public Health. Dieldrin and polychlorinated biphenols (PCB) were not detected in any of the fish. Concentrations of mercury did not exceed 20 percent of guideline limits for fish, nor did concentrations exceed 10 percent of guideline limits for DDT and its analogs in fish.

Waterfowl

Houk et al. (1975) found that the harvesting of ducks on Horseshoe Lake during the 1974 season was almost twice as productive as the best of 39 public hunting areas in Illinois and that the harvest of 1206 ducks exceeded that in 27 of the state areas. The dominant species harvested were the lesser scaup (46 percent of the total bag), mallards (28 percent), and ring necked ducks (8 percent). In general diving ducks accounted for 64 percent and puddle ducks 36 percent of the total bag. It was concluded that waterfowl hunting on the lake should be a high priority use.

Table 2. Content of Water Samples Taken After December 1977 Fish Kill
(Concentrations in milligrams per liter unless otherwise indicated)

| | <i>GCS effluent</i> | <i>At Quality Sand Company</i> | <i>In Nameoki Ditch</i> |
|---|---------------------|------------------------------------|-----------------------------|
| Ammonia-nitrogen | 0.25 | 1.5 | 0.15 |
| Nitrate and nitrite | 2.8 | 1.3 | 0.4 |
| Chloride | | 93 | 50 |
| Cyanide | 0.03 | 0.0 | 0.0 |
| Biochemical oxygen demand | 11 | 7 | 6 |
| Total solids by electrical conductivity | | 380 | 190 |
| Suspended solids | .9 | 6 | 40 |
| pH (units) | 7.3 | 7.4 | 7.6 |
| Dissolved oxygen | | 16.7 | 13.2 |
| Fecal coliform | | ND | 340 per 100 ml |

* ND = not detected

Water Quality Investigations

A definitive study for determining the water quality of the lake has never been undertaken. The water chemistry data available were gathered during abbreviated studies of limited scope, such as fish kill investigations, effluent monitoring, and biological studies.

Covich (1975) concluded that the wind-swept, shallow nature of the lake brings large quantities of silt particles into suspension and that the resultant high turbidity severely limits algae (phytoplankton) production, wind mixing of the lake water presumably keeps dissolved oxygen at or near saturation levels and accounts for the lack of observed thermal stratification. Covich cautions that there may be periods of deoxygenation during ice cover because of the lack of wind mixing and the productive nature of the lake. This deoxygenation might produce a "winter kill" of fish.

Tucker (1972) collected benthic samples from 11 stations in the lake during July 11-12, 1972. Benthic organisms were not found at any of the seven stations located near the GCS levee nor at the mouth of Nameoki Ditch. All of the organisms found at the other four stations were considered pollution tolerant.

On April 9, 1975, Hite (1975) collected benthic samples from the same stations that had been sampled by Tucker. Macroinvertebrates were recovered from all stations and consisted of the generally pollution-tolerant groups Oligochaeta (aquatic worms), *Chaoborus* (phantom midge), and Chironomidae (true midges). Lower numbers of individuals and taxa were evident at the two stations closest to the GCS discharge. Hite concluded that the lake was in a degraded condition based upon the lack of aquatic vegetation and mollusk populations and the presence of only tolerant aquatic macroinvertebrate fauna.

Covich (1975) reported that the typical benthic community of oxbow lakes comprises mainly the organisms found by Hite. He also reported that several species of aquatic gastropods were inhabiting the shore areas of the lake.

As part of the National Eutrophication Survey Program, the U.S. Environmental Protection Agency (1975) sampled Horseshoe Lake and three of its tributaries. The lake was sampled three times (in May, August, and October 1973) at two locations. Nameoki Ditch, Elm Slough, and the canal between the lake and the Cahokia Canal were sampled monthly from June 1973 to May 1974. It was concluded that Horseshoe Lake was in a eutrophic state and had persistent algal blooms with blue-green algae dominating all phytoplankton samples; that phosphorus was the limiting algal nutrient; and that the annual phosphorus loading rate of the lake was almost double that judged to be a "dangerous" rate (the rate at which receiving water becomes or remains eutrophic). It was also determined that Elm Slough contributed 39 percent of the annual phosphorus loading, Nameoki Ditch contributed 13 percent, and all other sources (including GCS discharge) contributed 48 percent. In addition, it was determined that 27 percent of the annual nitrogen loading was contributed by Elm Slough, 9 percent was contributed by Nameoki Ditch, 3 percent came from precipitation, and 34 percent was contributed by other sources, including GCS discharge.

Aquatic rooted vegetation in Horseshoe Lake is sparse, consisting of American lotus, large leaf pondweed, cattails, water primrose, and arrowhead. These plants tend to concentrate in areas sheltered from the wind, suggesting that wind-generated waves in the shallow lake render much of the lake bottom and shoreline unsuitable for rooted vegetation (Covich, 1975),

A recent study of sediments in the lake (Gross, 1978) indicates that within the top 24 inches of the sediment, zinc, lead, and cadmium are in concentrations considerably in excess of background levels. Surprisingly, iron and phosphorus were found at near background levels in the sediments despite the steel mill discharge and the reported phosphorus loadings into the lake.

Objectives and Scope

The principal objectives of this investigation were to assess and define the basic water quality characteristics of Horseshoe Lake, and to determine whether or not these characteristics limit certain proposed uses of the lake. The results of the study were considered essential for an informed understanding of the mechanisms governing the water quality of the lake system as well as for provision of input into a data base for policies regarding recreational development of the lake. Spatial and seasonal determinations of the physical, chemical, and biological components were designed to provide valuable insights into the limnology of the lake. The data were compared with observations made on other lake systems in Illinois,, Recommendations are offered that will be useful in the decision-making process regarding improvements in water quality and uses of the lake.

Acknowledgments

This investigation was sponsored and financially supported by the Illinois Department of Conservation (IDOC). It was conducted under the general guidance of Dr. William C. Ackermann, Chief Emeritus of the Illinois State Water Survey.

The following personnel, under the supervision of Ralph L. Evans, Head of the Survey's Water Quality Section, participated in various phases of this investigation: Davis B. Beuscher, John Crooks, David L. Hullinger, Dana Shackelford, and Rick Twait. Thomas A. Butts authored the sediment oxygen demand portion of the study. Linda J. Johnson typed the original manuscript and the camera copy: John W. Brother, Jr., Mary Carlson, Linda Riggan, and William Motherway, Jr., prepared the illustrations; and Gail Taylor edited the manuscript.

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the Illinois State Geological Survey; Thomas A. Prickett, formerly of the State Water Survey; and Robert L. Schleuger and William J. Tucker, both of the Illinois Environmental Protection Agency.

Special thanks are due two concerned lake residents, Bob Becker and William F. Nichols, who provided invaluable local assistance.

SAMPLE COLLECTION AND LABORATORY PROCEDURES

Nine sampling stations were established on the lake system, as shown in figure 1. Samples were collected at all the stations at approximately mid-depth. At station 5 - located at the deep hole in the lake - two samples were collected: a sample 1 foot from the surface (sample 5t) and a sample 3 feet from the bottom (sample 5b).

Sampling trips were made to the lake approximately every 2 weeks from May 25, 1978, to January 23, 1979, for a total of 17 visits.

Station 1 was located approximately 5 . feet from shore, in the extreme southwestern arm of the lake. This portion of the lake has been known to dry up completely. During this study, on September 13, 1978, the station was moved farther into the lake because of low water levels.

Station 2 was established in the center of the contiguous southwestern arm of the lake.

Station 3 was located in the center of the leveed section of the lake, about 3 . . feet northeast of the GCS discharge pipe.

The influence of the Nameoki Ditch inflow was assessed by analysis of the data from station 4, located at the mouth of the ditch.

At station 5, located in the vicinity of the sand dredge, two samples were taken routinely at different depths, as was explained previously. These samples were representative of the epilimnion and hypolimnion during thermal stratification.

Station 6 was near the confluence of Elm Slough and Horseshoe Lake, and station 7 was located in the middle of the eastern arm of the lake, approximately 45 . feet north of the Causeway.

Station 8 was established near the delta area, as far down the central arm as depth would permit, and station 9 was located just south of Route 111, on the canal that connects the lake with the Cahokia Canal.

Field Measurements

During each sampling trip, *in situ* measurements for water temperature, dissolved oxygen, transparency, and depth were made at each station; air'tem-

perature and general weather conditions were recorded at each station; and the direction of flow in the discharge canal, use of the low flow (weir) structure, and flow over the spillway (if such occurred) were noted. At the end of each sampling day, alkalinity and pH were determined from the samples collected (figure 3),,

Water temperature and dissolved oxygen profiles were made through the use of a galvanic cell oxygen analyzer equipped with a thermister. A dissolved oxygen meter, Yellow Spring Instrument Company model 57 with a 5 . -foot cable, was used for this purpose. At the beginning of each day of measurement, the probe was standardized in lake water in which the dissolved oxygen content was determined by a modified Winkler method as outlined by the American Public Health Association (1971).

An 8-inch diameter Secchi disc with black and white quadrant markings attached to a calibrated line was used to measure water transparencies and total water depth (figure 4). The disc was lowered until it disappeared from view, lowered farther, and then raised slowly until it reappeared. The depth of each immersion was noted, and the average of the two observations was recorded as the Secchi disc reading. The Secchi disc was then lowered vertically to the bottom and the water depth was recorded. A Heathkit Depth Sounder (model MI-11A) frequently was used to find station 5 and measure its depth.

Alkalinity and pH analyses were performed in the field with the use of a portable Metrohm-Herisau pH meter (model E588). The alkalinity was titrated to a pH of 4.5 with 0.02 $\text{NH}_2 \text{SO}_4$, using 50-ml samples.

Water Sampling

Water samples were taken at a depth of 1 foot by inverting a quart plastic bottle by hand. The deep samples (samples 5b) at station 5 were obtained with a Kemmerer sampler. Samples were stored on ice until transported to the laboratory, where they were refrigerated at 4°C until chemical analyses were performed.

At the time of collection, samples for ammonia determinations received special handling. A 5 . -ml portion of the water samples was filtered through type HA, 0.45 μ millipore filters 37 mm in diameter. The filters were placed on filter pads held between two-piece circular holders, and positive pressure for filtering the samples was provided by a syringe to force the samples through the filter. The filtrates were collected in small plastic bottles. (Micro-pore filtration eliminates any bacterial activity that could alter the ammonia concentration in the collected samples during storage. This method of sample preservation is considered superior to acidification or other chemical additives.)

Chemical analyses of all water samples were performed routinely for ammonia-nitrogen, total phosphorus, dissolved phosphorus, suspended solids, dissolved solids, and turbidity.

Water turbidity was determined by the nephelometric method with a G. K. Turner Fluorometer. The emission light was reduced with 1-percent and 10-per-

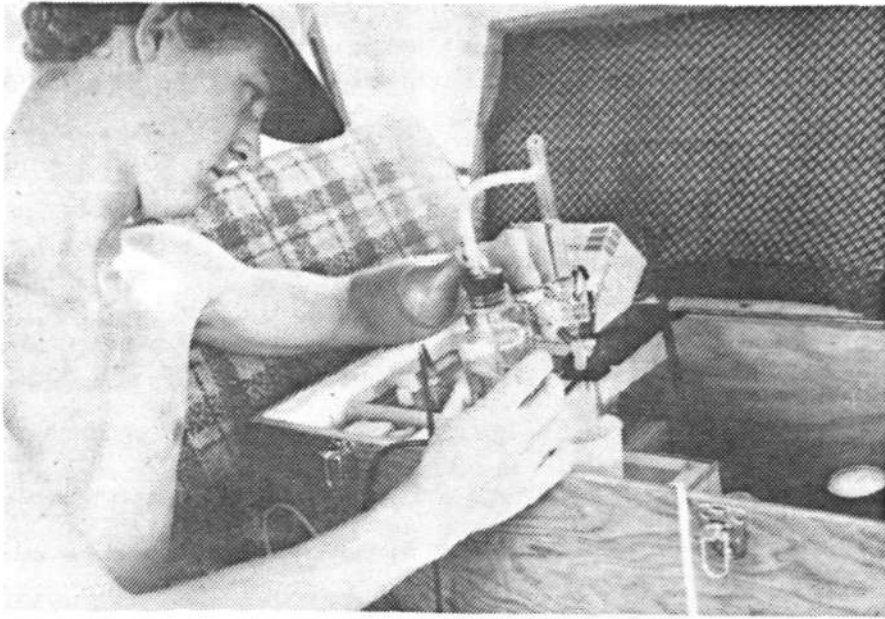


Figure 3. Field alkalinity and pH determinations



Figure 4, Secchi disc measurements

cent light transmission filters. With formazin as an artificial standard, as described by the American Public Health Association (1971), the calibration curve showed a linear relationship up to 80 units. (Proper dilution is necessary as the response flattened at the higher concentration.) Turbidity was expressed as nephelometric turbidity units (NTU).

Procedures for performing chemical analyses set forth by the American Public Health Association (1971) were used. A summary of the procedures is included in table 3.

In addition to the samples collected routinely, water samples were collected at all stations on three dates (July 5, 1978, September 27, 1978, and January 8, 1979) and were acidified in the field with nitric acid. These samples were analyzed for zinc, iron, copper, lead, manganese, and cadmium.

Table 3. Laboratory Analytical Procedures

| | |
|---------------------------|---|
| Ammonia-N | Phenate method |
| Total phosphorus | Sample was digested with sulfuric-nitric acids mixture and determined by ascorbic acid method |
| Dissolved orthophosphorus | Ascorbic acid method after filtration through 0.45 μ filter paper |
| Suspended solids | Nonfilterable residue through Gooch crucible, dried at 103-105°C |
| Dissolved solids | Total filtrable residue by evaporation, dried at 103-105°C |
| Hardness | EDTA titrimetric method |
| Chloride | Argentometric method |
| Sulfate | Turbidimetric method |
| Nitrate-N | Chromotropic acid method |
| Fluoride | Electrode method |
| Chlorine (residual) | Iodometric method |
| Iron | Digestion with nitric acid, atomic absorption spectrophotometry |
| Manganese | Digestion with nitric acid, atomic absorption spectrophotometry |
| Copper | Digestion with nitric acid, atomic absorption spectrophotometry |
| Cadmium | Digestion with nitric acid, atomic absorption spectrophotometry |
| Lead | Digestion with nitric acid, atomic absorption spectrophotometry |
| Zinc | Digestion with nitric acid, atomic absorption spectrophotometry |
| Calcium | Atomic absorption spectrophotometry |
| Magnesium | Atomic absorption spectrophotometry |
| Potassium | Atomic absorption spectrophotometry |
| Sodium | Atomic absorption spectrophotometry |

Additional analyses were performed on the January 8 water samples for hardness, nitrate-nitrogen, fluoride, chloride, sulfate, potassium, sodium, calcium, and magnesium.

While the routine water analyses were being performed on the samples collected on January 22, 1979, the distinct odor of chlorine was noted in several samples. All the samples for that date were then further analyzed for residual chlorine.

Macroinvertebrates

Benthic macroinvertebrates were collected from all stations except station 9 approximately once a month, for a total of nine collections. Each sample consisted of three composited 6x6-inch Ekman dredge grabs. The benthic samples were washed at each station through a U. S. Standard 30-mesh sieve bucket and preserved in 95 percent ethyl alcohol. In the laboratory, the organisms were picked from the detritus, identified, counted, and preserved.

- In addition to the regular benthic samples collected in deeper water, one collection of macroinvertebrates was made in the shore areas of the lake. On August 2, 1978, non-quantitative samples were collected with an aquatic dip net in the shore areas closest to the regular benthic sampling stations. The samples were processed as described previously.

Algae

Algae samples were collected on each trip and at all stations except station 9. All the water samples for algal analyses were collected at the surface except for sample 5b, which was collected with a Kemmerer sampler. Samples were stored in a 380-ml, small-mouth glass bottle and preserved with 10 ml of formalin.

Examinations were generally performed within 2 weeks, at which time the sample was thoroughly mixed and a 1-ml aliquot was pipetted into a Sedgwick-Rafter counting cell. If the algal counts were found to be low, a 50-ml aliquot was passed through a millipore HA filter (0.45 μ pore diameter). The residue was mixed in 10-ml of filtrate, and a 1-ml aliquot was then examined. A differential interference contrast microscope with 10X eyepieces, 20X or 40X objective, and a Whipple disc was used for identification and enumeration. Appropriate conversion factors were used to extrapolate the results to individuals per milliliter.

Zooplankton

Stations 2, 3, 5, and 7 were sampled for zooplankton on each sampling trip. Samples were collected by filtering 2 or 4 liters of lake surface water through a Wisconsin plankton net, and the concentrated zooplankton were preserved in the field with 95 percent ethyl alcohol. In the laboratory, the total volume for each sample was diluted to 200 ml with deionized water, the

sample was thoroughly mixed, and a 1-ml aliquot was pipetted into a Sedgwick-Rafter cell. Enumeration and identification were accomplished with the same equipment and general procedures employed for the algae.

Macrophytes

On August 31, 1978, a synoptic survey was made to determine the species composition of the aquatic and semiaquatic plants inhabiting the shores of the lake. Shore areas were visited by boat and on foot and the macrophytes found were identified. Subjective estimates of the dominant plants and the general areas occupied by each were recorded.

Sediment Oxygen Demand

Sediment oxygen demand (SOD) measurements were conducted at stations 2, 3, 4, 7, and 8 on three occasions in 1978: June 27-28, August 30-31, and October 25-26.

In situ measurements were made using a box-type respirometer with a known volume. The chamber, which contained a galvanic cell oxygen probe with an attached stirrer, was lowered to the bottom and sealed. A chart recorder, attached to a dissolved oxygen meter, monitored the oxygen depletion inside the test chamber. A detailed description of the methodology used has been reported by Butts and Evans (1978).

Nocturnal Dissolved Oxygen

On the night of August 16 and the morning of August 17, 1978 dissolved oxygen and water temperature measurements were taken in the lake. At station 5, a dissolved oxygen meter was used to obtain hourly profiles of dissolved oxygen and water temperature from 6 p.m. to 6 a.m.. At each of five other stations (stations 2, 3, 4, 6, and 7), three surface measurements were taken at various times during that period.

RESULTS

As noted previously, the study period extended from May 25, 1978, to January 23, 1979. Field measurements and sampling were performed approximately every 2 weeks during this period, and two days at the lake site were usually required to accomplish the tasks. All pertinent data gathered during the study are included in the appendices. All results of the study are reported except for those obtained for sediment oxygen demand examination, which have been reported separately by Butts and Evans (1979) and so will not be discussed here in great detail. The examination of the results includes little evaluation of station 1 as an in-lake influence, since it is an extremely shallow station, is atypical of the other stations, and is often isolated from the main body of the lake.

Water Depth

Except during times of flood water diversion from the Cahokia Canal into the lake, the water depth of the lake is a function of the manipulation of the low flow structure depicted in figure 5. With lake water at the crest of the spillway (figure 6), the average depths of water at the sampling stations (excluding station 5) were:

| <i>Station</i> | <i>Water depth (inches)</i> | <i>Station</i> | <i>Water depth (inches)</i> |
|----------------|---------------------------------|----------------|---------------------------------|
| 1 | 24 | 6 | 35 |
| 2 | 48 | 7 | 33 |
| 3 | 42 | 8 | 27 |
| 4 | 24 | 9 | 37 |

From May to mid-August 1978 the low flow structure was open, permitting a declining water level. The general effects this had on the water depths in the lake at sampling stations 1, 2, 4, and 7 are shown in figure 7. Often the water depths were less than 20 inches, and at station 1 they were sometimes less than 10 inches. After mid-August the low flow structure was closed and water depths gradually increased, reaching a maximum at the spillway on November 29, 1978, when flows were about 5 inches above the crest. Within the period from May to November 1978 there was approximately a 23-inch fluctuation in water depth.

The lowering of the lake's water level during summer months provides two benefits in addition to increasing the storm water retention capacity of the lake: it minimizes shore erosion, and it permits the sowing of seed, thus encouraging the growth of volunteer vegetation that will attract waterfowl. The rise in water levels later in the year provides a feeding ground for waterfowl and adequate access for hunting purposes. However the present management of the water level is of questionable benefit to the lake's fishery.

Water Temperature

Lakes in Illinois generally undergo seasonal temperature changes throughout the water column. Impoundments in excess of 15 to 18 feet will usually stratify in terms of temperature and dissolved oxygen (Kothandaraman and Evans, 1971). Unless a lake is quite sheltered by vegetation or topography and its bottom exhibits an excessive demand for dissolved oxygen, it is not likely that shallower lakes will stratify. This was the case for Horseshoe Lake, where all stations (except station 5, located at the deep hole of the lake) were isothermal throughout their water depth. There were, however, minor differences recorded for water temperature between the stations. As shown in figure 8, water temperatures during July and early August averaged between 3 . and 34°C. Temperatures at stations 1 and 9 were generally higher because they were usually recorded in mid-afternoon. Often water temperatures at the same station for the same day differed from 4 to 5°C between morning and afternoon, suggesting that the shallowness of the lake makes its waters quite sensitive to prevailing air temperatures. The water temperature in the vicinity of station 3 averaged about 1 . 5°C warmer than those stations closest to it,

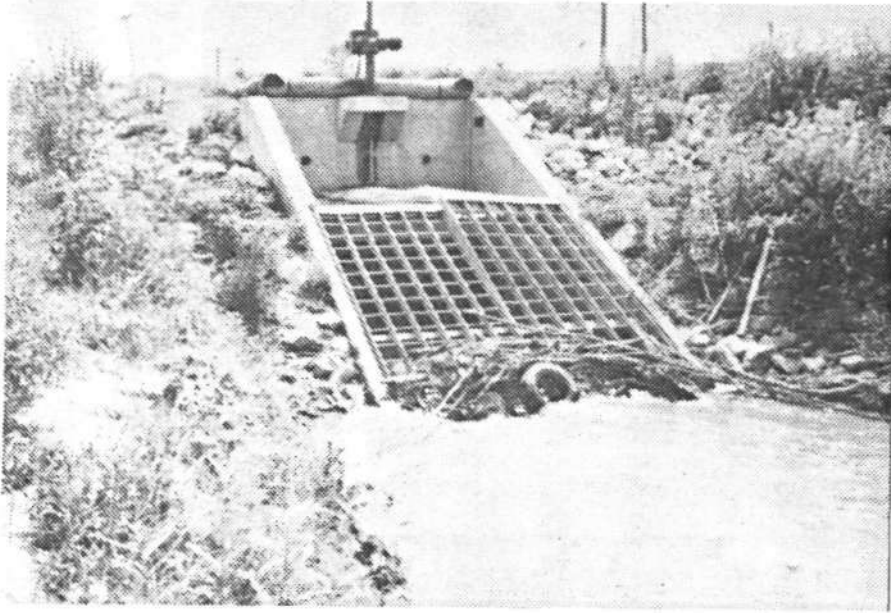


Figure 5. Structure for lowering lake levels below spillway level



Figure 6. Horseshoe Lake spillway (lower right) and flood water diversion structure on the Cahokia Canal

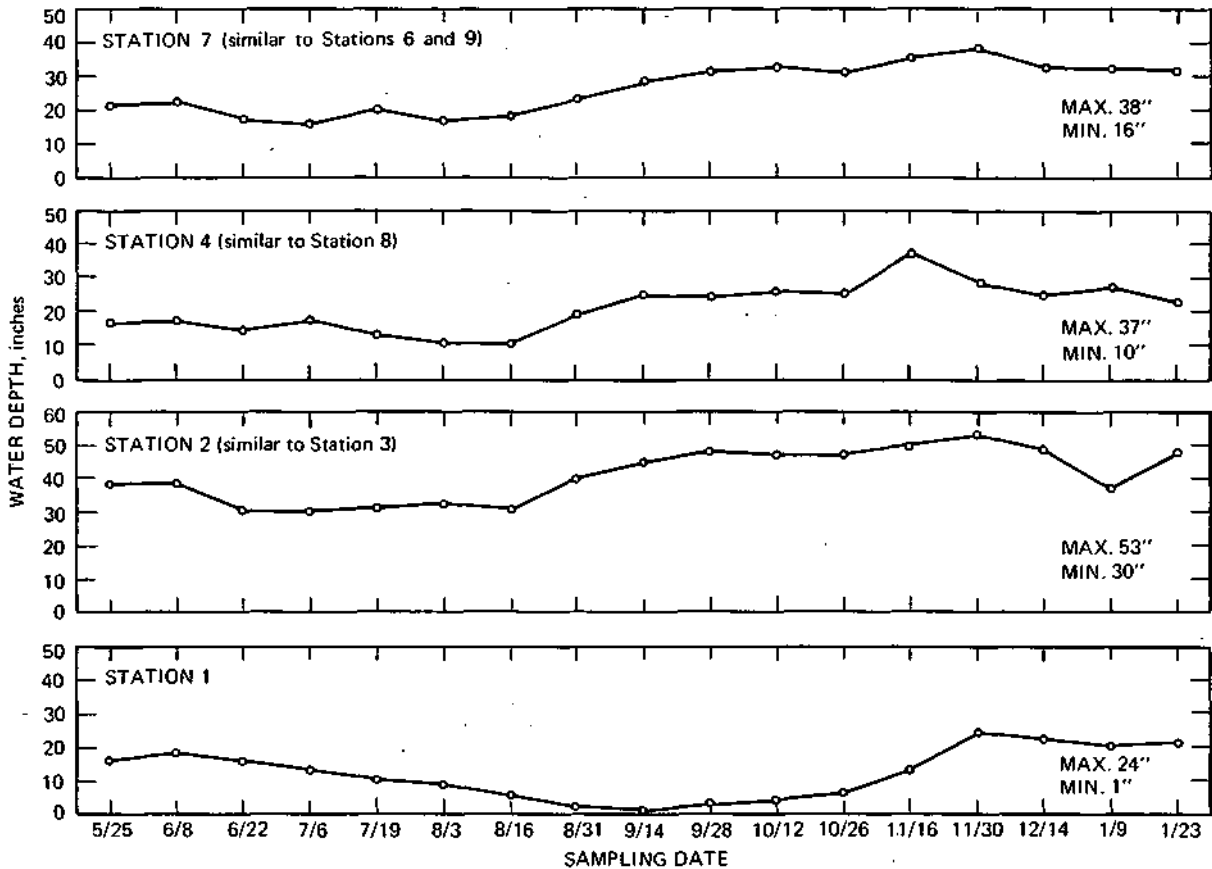


Figure 7. Water depths, Horseshoe Lake

probably due to the modifying influence of effluent discharges,, From a practical standpoint, the water temperatures of Horseshoe Lake are homogenous without significant variation vertically or spatially, except for the deep hole in the lake system. Figure 8 depicts the annual temperature cycle likely to occur.

As do deeper Illinois lakes, the deep hole at station 5 stratified thermally, as shown in figure 9. Thermal stratification was underway in May, and during the course of the summer months the bottom waters never exceeded 18°C, while water temperatures at the surface reached 30°C. Such stratification isolates the upper water layers from the lower water layers, resulting in profound effects, on the dissolved oxygen regime of the water column. Destratification occurred in late September, and the water column was isothermal thereafter.

Dissolved Oxygen

The dissolved oxygen content of lake waters is a function of many factors. In lakes where thermal stratification is pronounced, the important period from the standpoint of water quality is that of summer stagnation. As described earlier, thermal stratification does not play an important role in most of the waters of Horseshoe Lake. Rather, the major influences on its dissolved oxygen resources are surface reaeration, photosynthesis and the respiration of algae, soluble oxygen demand mediated by bacteria, and sediment oxygen demand. The predominant governing influence is probably algae.

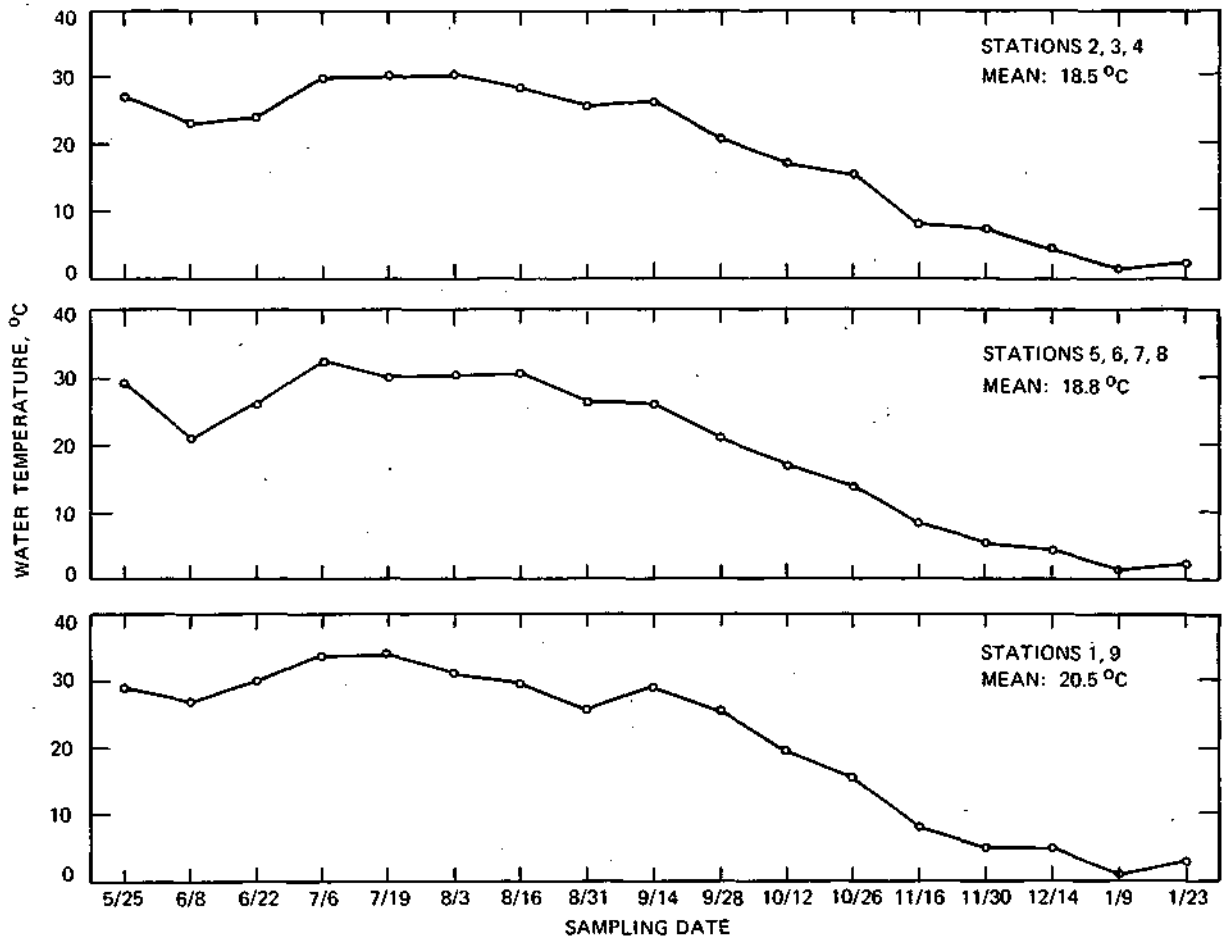


Figure 8. Water temperatures, Horseshoe Lake

As with temperature, there is no significant stratification of dissolved oxygen concentration in Horseshoe Lake. Mean values and observed ranges are included in table 4. At no time during daytime measurements were concentrations of dissolved oxygen less than 5.4 mg/l in the main body of the lake except in the deep hole at station 5. The major differences shown in the mean values for stations 2, 3, 4, and 5 compared to those for stations 6, 7, and 8 are probably due to the time of day the measurements were performed. Measurements for the first group of stations were made visually during the morning, while those for the latter group were usually performed during the afternoon. On the average, about 2-3 mg/l difference in dissolved oxygen concentration occurred between mid-morning and mid-afternoon due to algal activity.

The surface waters of productive lakes may experience a depression of oxygen levels during the night. On August 16-17 nocturnal dissolved oxygen measurements were performed at stations 2, 3, 4, 5, 6, and 7. The overall period of time and the intervals of measurement varied because of boat travel time between stations. The results are summarized in table 5. This was a very productive period in terms of algal density, and this should be kept in mind. Initial dissolved concentrations varied from 8.6 to 15.2 mg/l, and the overall average rate of oxygen depression varied from 0.3 to 0.4 mg/l/hr for stations 2, 3, and 5 and from .8 to .9 mg/l/hr for stations 4, 6, and 7. At these rates it would not be unreasonable to expect that during the summer months between 6 p.m. and 6 a.m., dissolved oxygen concentrations would de-

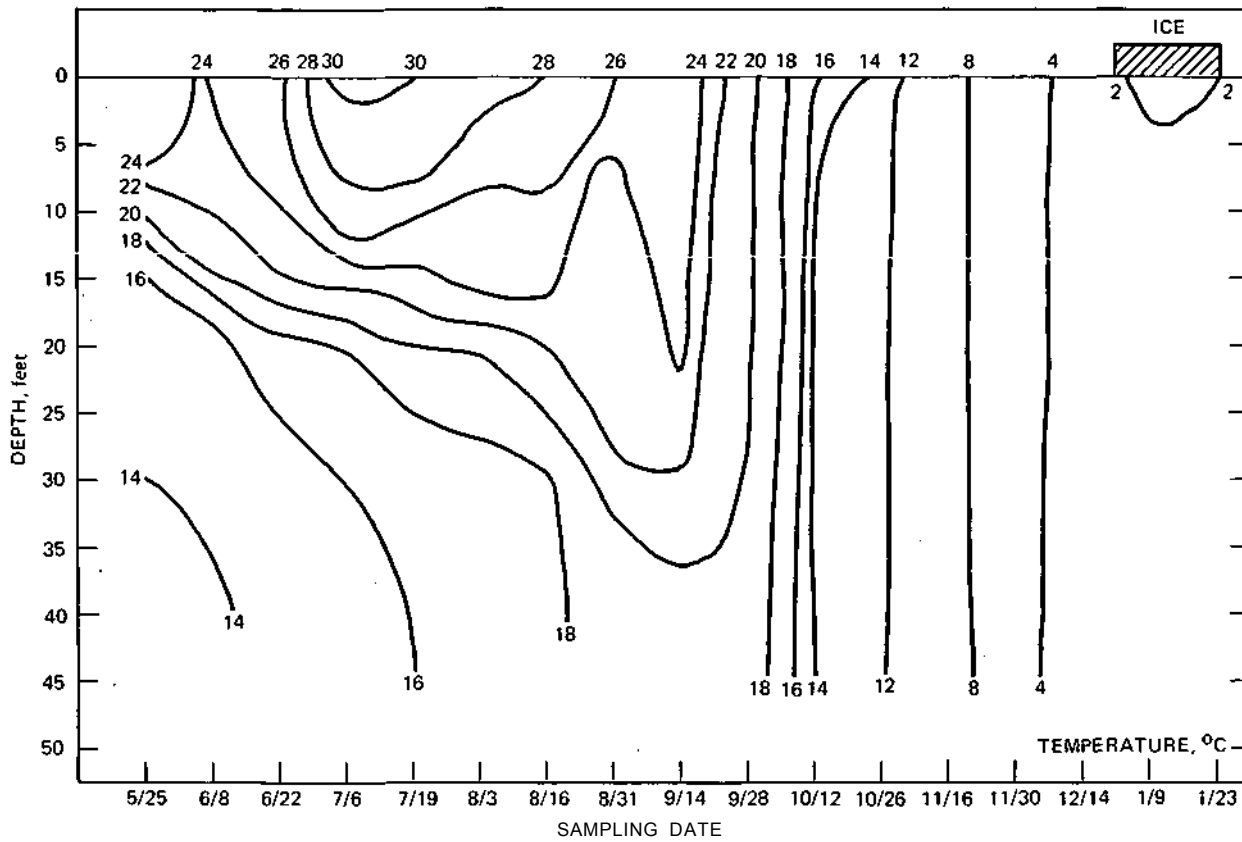


Figure 9. Isothermal plots for station 5, Horseshoe Lake

Table 4. Dissolved Oxygen Concentrations
(Milligrams per liter)

| Station | Mean values | Range |
|-------------------|-------------|----------|
| 1 | 13.7 | 6.3-20+ |
| 2 | 8.7 | 5.8-11.1 |
| 3 | 7.9 | 5.5-12.3 |
| 4 | 7.9 | 5.4-10.8 |
| 5 (surface water) | 8.0 | 5.4-15+ |
| 6 | 10.3 | 5.3-13.2 |
| 7 | 11.2 | 7.5-14.5 |
| 8 | 10.8 | 6.5-15+ |
| 9 | 8.8 | 2.7-13.6 |

Table 5. Nocturnal Oxygen Changes

| Station | Measurement | | Initial DO (mg/l) | Final DO (mg/l) | Depression rate (mg/l/hr) |
|---------|-----------------------|-------------------|----------------------|--------------------|---------------------------------|
| | Overall time (hrs) | interval (hrs) | | | |
| 2 | 8 | 4 | 12.0 | 8.5 | 0.4 |
| 3 | 8 | 4 | 8.6 | 6.3 | 0.3 |
| 4 | 8 | 4 | 13.2 | 6.0 | 0.9 |
| 5 | 12 | 1 | 9.4 | 4.2 | 0.4 |
| 6 | 7 | 4&3 | 14.0 | 8.4 | 0.8 |
| 7 | 7 | 4&3 | 15.2 | 8.8 | 0.9 |

crease 4 to 1 . mg/l from initial daytime concentrations. This suggests that the dissolved oxygen levels in this shallow lake may be less than 4 mg/l during nocturnal conditions.

The deep hole at station 5 did stratify with regard to dissolved oxygen. The isopleths are shown in figure 1 . . In late May concentrations of 1 . . mg/l or less of dissolved oxygen existed at 15 feet below the water surface. During most of July oxygen was depleted in the water column at depths greater than 1 . feet below the water surface, which is typical for Illinois waters during the summer months. Non-stratified conditions were finally attained in November.

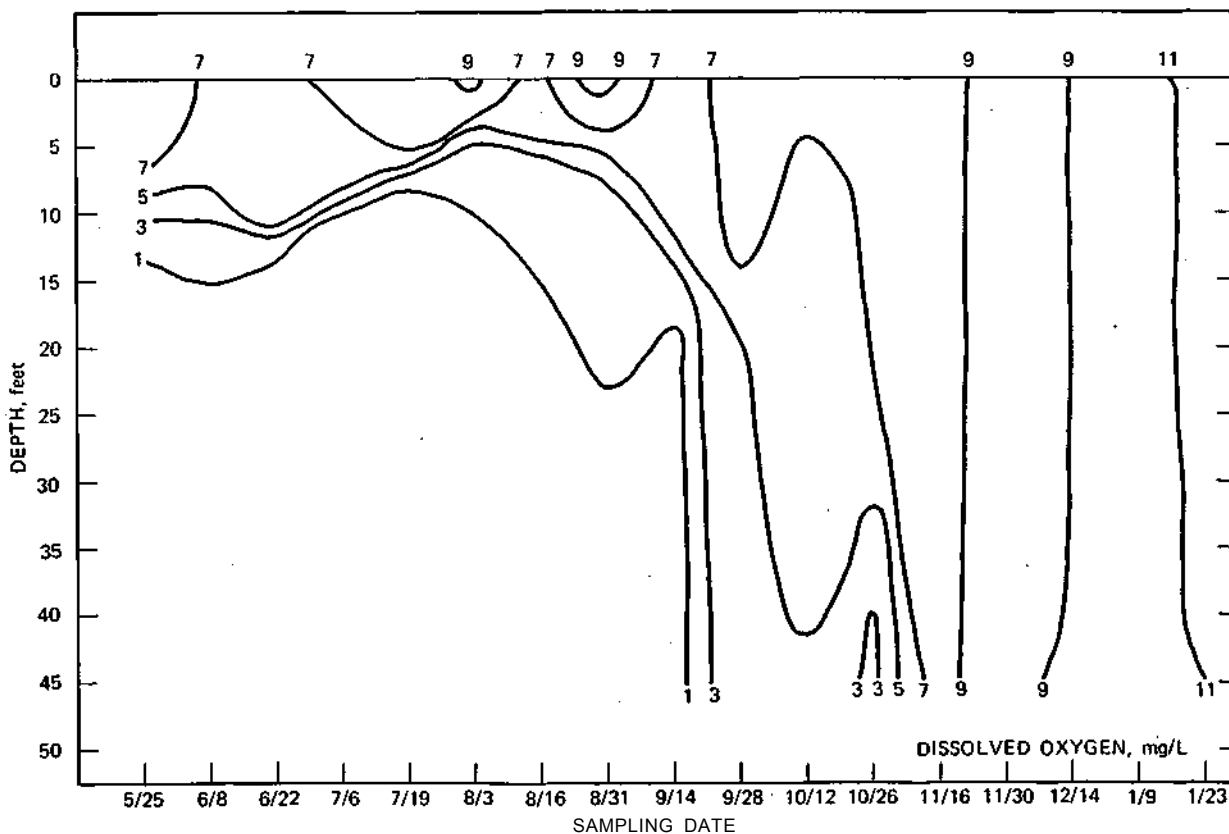


Figure 10. Isopleths of dissolved oxygen at station 5, Horseshoe Lake

Water Transparency

The transparency of lake water, as measured by Secchi disc observations, is an estimate of the ability of the water to allow light transmission at the surface. Transparency is related to water color, suspended sediment consisting of silt and clay, and algal density. The mean values and ranges observed for Secchi disc measurements in Horseshoe Lake are shown in table 6.

In most lakes in central and southern Illinois that are more than 2 . feet deep, mean Secchi disc observations range from 3 . to 4 . inches (Roseboom et al., 1979a, 1979b; Illinois State Water Survey, 1978). However in shallower eutrophic lakes of 3 to 8 feet in depth, Secchi disc readings average about 1 . inches (Kothandaraman et al., 1977). In terms of water clarity Horseshoe Lake is not unlike other shallow lakes in Illinois.

Typical seasonal water clarity observed in Horseshoe Lake is shown in figure 11. It is quite obvious that the transparency of water at station 3 exceeds that at other stations. Statistical evaluations of relationships between turbidity measurements, concentrations of suspended solids, and Secchi disc values were performed. Correlation coefficients for these relationships were significant at a confidence level of 95 percent. The equations of best fit and correlation coefficients for Secchi disc vs turbidity are shown in table 7. An examination of intercepts and slopes for the mathematical relationships at each station indicates similarity among certain stations. Based on similarities it is logical to group stations 2, 3, and 5 and stations 4, 6, 7, and 8. It is equally logical to conclude that effluent discharges in the vicinity of station 3 have a beneficial effect on water transparency at that station as well as at stations 2 and 5.

Equations of best fit and corresponding correlation coefficients for the relationships between Secchi disc and algal densities are included in table 8. Here, too, correlations are significant at the 95 percent level of confidence. Based on mathematical similarities the stations are shown in three groups. In two groups (stations 2, 3, 5 and 6, 7, 8) it appears that 56 to 90 percent of the variations in Secchi disc observations is attributable to algae densities. It is probable that Nameoki Ditch drainage in the vicinity of station 4 may be the influential factor isolating that station from the mathematical similarities of the others.

It is understood that other statistical procedures could have been used to determine significant differences between stations and to group stations, but the procedures used here permit a pattern of analysis to be followed in subsequent discussions.

As was mentioned previously, the water transparency of lake waters is governed by water color, suspended clay and silt particles, and algal density. From an evaluation of the data it is clear that algal densities are a predominant factor.

Suspended Solids and Turbidity

No good historical record is available of the measurement of suspended solids in Illinois lakes. In determining water clarity and the influence

Table 6. Secchi Disc Measurements

| <i>Station</i> | <i>Mean (inches)</i> | <i>Range (inches)</i> |
|-------------------|--------------------------|---------------------------|
| 2 | 21 | 5-53 |
| 3 | 24 | 9-48+ |
| 4 | 12 | 6-25+ |
| 5 (surface water) | 16 | 7-42 |
| 6 | 12 | 4-34 |
| 7 | 11 | 5-29 |
| 8 | 11 | 3-28 |

Table 7. Secchi Disc vs Turbidity

| <i>Station</i> | <i>Equation of best fit</i> | <i>r</i> |
|----------------|-----------------------------|----------|
| 2 | $y = 35.7 - 1.37x$ | -0.07 |
| 3 | $y = 31.9 - 1.05x$ | -0.47 |
| 5 | $y = 29.6 - 1.24x$ | -0.61 |
| 4 | $y = 19.3 - 0.45x$ | -0.69 |
| 6 | $y = 24.2 - 0.66x$ | -0.82 |
| 7 | $y = 22.0 - 0.55x$ | 0.83 |
| 8 | $y = 19.5 - 0.34x$ | 0.76 |

Note: y = Secchi disc (inches)
 x = turbidity (NTU)
 $y = a + bx$

Table 8. Secchi Disc vs Log Algal Density

| <i>Station</i> | <i>Equation of best fit</i> | <i>r</i> |
|----------------|-----------------------------|----------|
| 2 | $y = 77.9 - 15.0x$ | -0.93 |
| 3 | $y = 55.9 - 9.1x$ | -0.76 |
| 5 | $y = 54.3 - 10.4x$ | -0.91 |
| 4 | $y = 12.8 - 0.17x$ | -0.59 |
| 6 | $y = 38.9 - 7.2x$ | -0.94 |
| 7 | $y = 31.1 - 5.2x$ | -0.75 |
| 8 | $y = 37.1 - 6.9x$ | -0.95 |

Note: y = Secchi disc (inches)
 x = log algal density
 $y = a + bx$

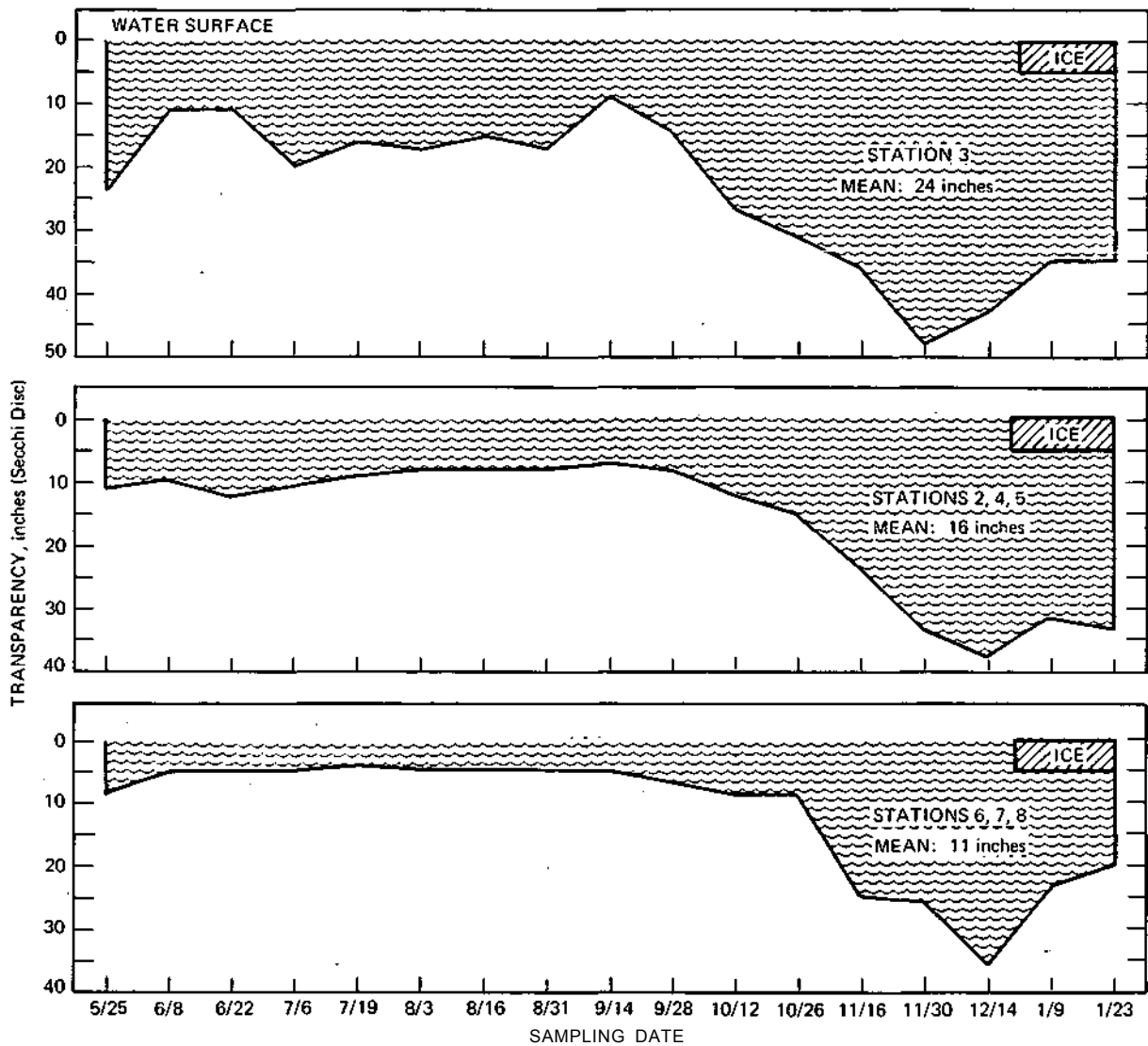


Figure 77, Water transparency, Horseshoe Lake

of suspended matter in the water on the transmittance of light, almost total reliance has been placed on Secchi disc observations, although recently some turbidity measurements have been recorded. However the determination of suspended solids in natural waters has been limited to flowing streams where sediment transport is a prime consideration,, Measurements of suspended solids were performed at Horseshoe Lake because of the speculation that excessively turbid conditions in that shallow lake were probably the result of disturbed bottom sediment caused either by wind or boats.

Because of the nature of suspended solids determinations (quantities of water samples are filtered and the residue weighed), a variety of substances make up the suspended solids, principally silt and clay particles and algae. However, since the turbidity measurement is based upon the scattering of light,

turbidity is not only a function of the number of particles (silt, clay, or algae) but also of the shape and size of the particles and of the water color.

As expected, the suspended solids concentrations and turbidity in Horseshoe Lake were quite variable both temporally and spatially. The mean values and ranges for each of the in-lake stations are shown in table 9,,

Based upon mean values the stations were considered in two groups for data reduction and comparison - stations 2, 3, and 5 and stations 4, 6, 7, and 8. Although information is sparse for such data on Illinois lakes, earlier work (Kothandaraman et al., 1977) on the Fox Chain of Lakes produced comparative observations for some shallow lakes in that lake system. The comparisons with Horseshoe Lake groupings are presented in table 10.

This comparison of Horseshoe Lake with the shallow lakes of glacial origin in the Fox Chain suggests that there is no significant difference in their respective suspended solids content or turbidity.

Table 9. Suspended Solids and Turbidity

| Station | <u>Suspended solids (mg/l)</u> | | <u>Turbidity (NTU)</u> | |
|---------|--------------------------------|-------|------------------------|-------|
| | Mean | Range | Mean | Range |
| 2 | 42 | 3-192 | 11 | 1-33 |
| 3 | 29 | 1-200 | 7 | 2-21 |
| 4 | 62 | 9-202 | 16 | 4-39 |
| 5 | 27 | 1-54 | 11 | 4-22 |
| 6 | 56 | 7-136 | 18 | 3-39 |
| 7 | 68 | 3-148 | 20 | 4-27 |
| 8 | 99 | 4-266 | 23 | 3-45 |

Table 10. Suspended Solids and Turbidity in the Fox Chain of Lakes and in Horseshoe Lake

| Lake | Depth (feet) | <u>Suspended solids (mg/l)</u> | | <u>Turbidity (NTU)</u> | |
|---------------------|-----------------|--------------------------------|--------|------------------------|-------|
| | | Mean | Range | Mean | Range |
| Nippersink | 4.9 | 60 | 33-144 | 28 | 17-45 |
| Pistakee | 5.4 | 56 | 15-138 | 24 | 15-32 |
| Grass | 3.5 | 72 | 22-432 | 21 | 10-44 |
| Stations 2, 3, 5 | | 33 | 1-200 | 10 | 1-39 |
| Stations 4, 6, 7, 8 | | 71 | 3-266 | 26 | 3-45 |

The spatial and temporal variations of the stations in Horseshoe Lake for suspended solids and turbidity are shown in figures 12 and 13, respectively. Note that the ordinate scale for suspended solids (figure 12) is different for the two groups of stations. However the pattern of relatively high concentrations during May through August, with a general trend of reduction thereafter, is similar and corresponds to water transparency patterns depicted in figure 11. Variations in turbidity are also similar. The relative reduction in suspended solids content at stations 2, 3, and 5 compared to that at stations 4, 6, 7, and 8 is due to the modifying influence of the effluent discharges in the vicinity of station 3.

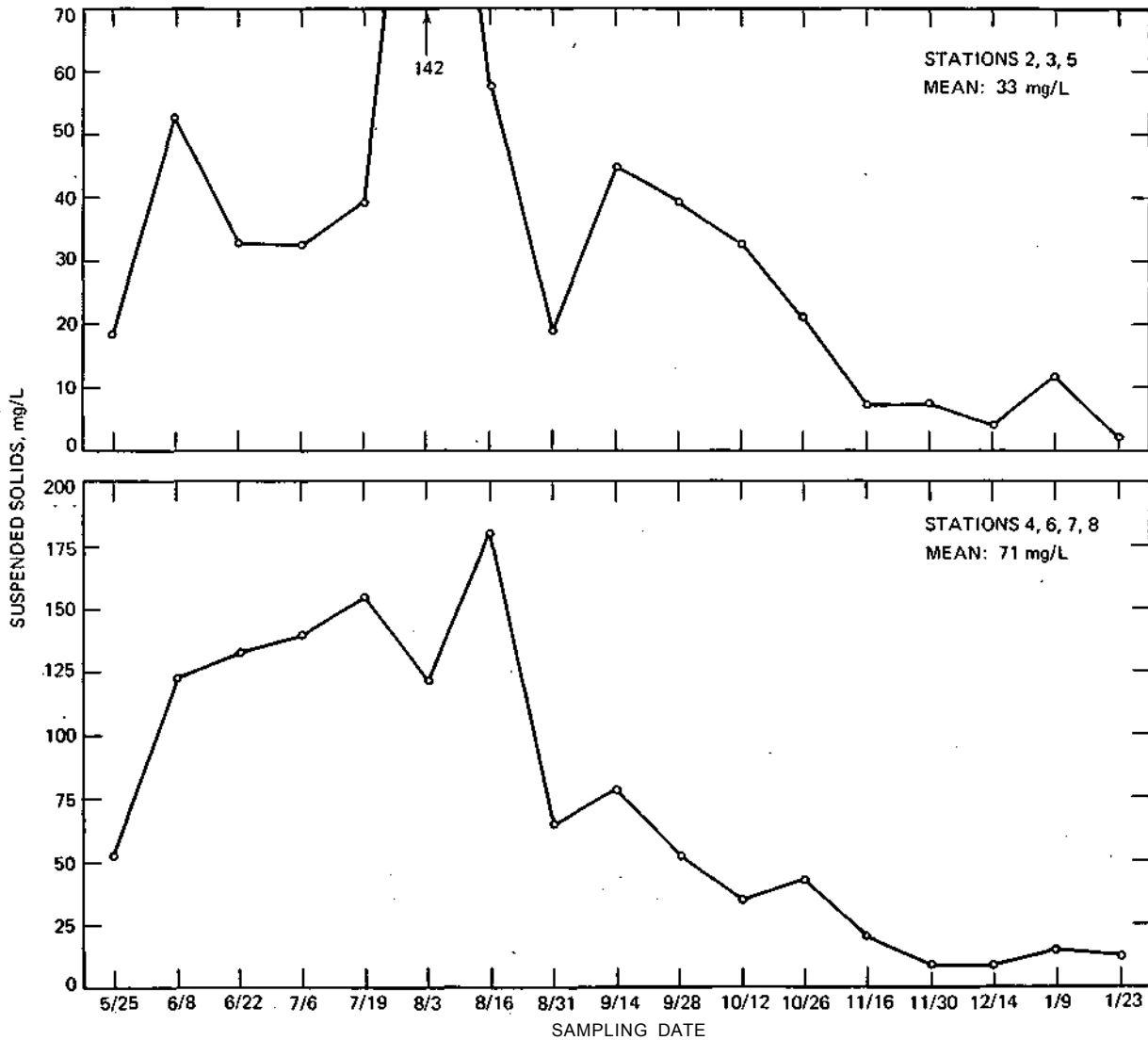


Figure 72. Suspended solids, Horseshoe Lake

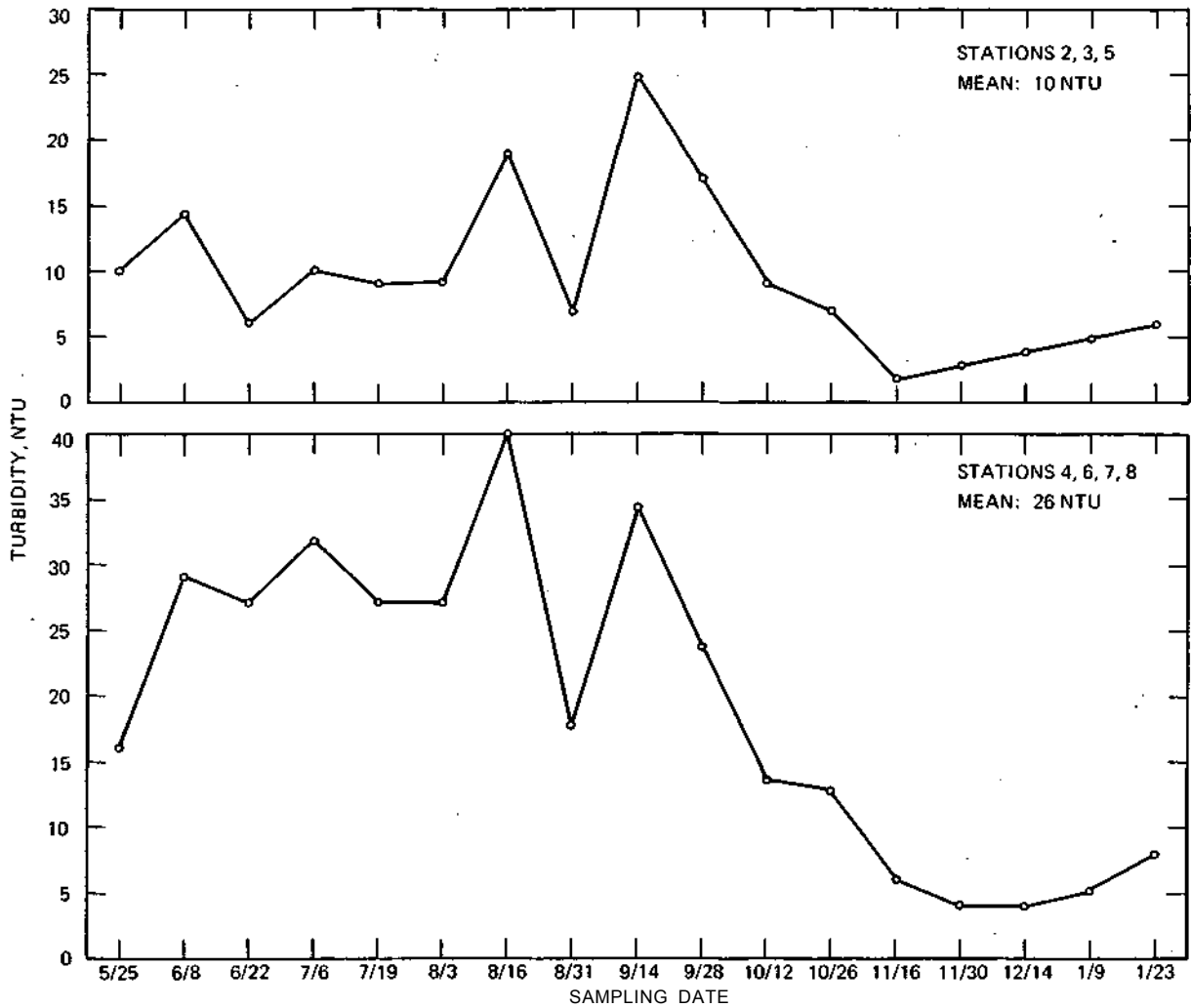


Figure 73. Turbidity, Horseshoe Lake

The statistical relationships between turbidity and suspended solids are shown in table 11. The relationships are significant at a confidence level of 95 percent, and with some reliability it can be concluded that suspended solids concentrations account for 49 to 73 percent of the variations in turbidity.

To examine the probable nature or origin of the suspended solids, an examination was made of the statistical relationships that may exist between that constituent and algal density. These are included in table 12. With the exception of station 3 the relationships are significant at the 95 percent level of confidence. In essence what these relationships suggest is that 41 to 62 percent of the variations in suspended sediment concentrations is due to algal densities. On this basis it is logical to assume that 38 to 59 percent of the variations in suspended solids concentration is attributable to the re-suspension of bottom sediment in the lake. The flocculent nature of the bottom sediments in the lake has been described by Butts and Evans (1979). A reasonable assumption is that about 5 . percent of suspended solids in the lake system come from algae and 5 . percent come from the lake bottom.

Table 11. Turbidity vs Suspended Solids

| Station | Equation of best fit | r |
|---------|----------------------|------|
| 2 | $y = 0.79 + .34x$ | 0.85 |
| 3 | $y = 2.9 + .21x$ | 0.69 |
| 4 | $y = 6.1 + .15x$ | 0.84 |
| 5 | $y = 3.3 + .28x$ | 0.73 |
| 6 | $y = 4.8 + .24x$ | 0.88 |
| 7 | $y = 6.1 + .21x$ | 0.87 |
| 8 | $y = 7.2 + .17x$ | 0.88 |

Note: y = turbidity (NTU)
 x = suspended solids (mg/l)
 $y = a + bx$

Table 12. Suspended Solids vs Log Algal Density

| Station | Equation of Best Fit | r |
|---------|----------------------|------|
| 2 | $y = -29.7 + 16.1x$ | 0.71 |
| 3 | $y = -0.41 + 6.0x$ | 0.35 |
| 4 | $y = -70.9 + 36.6x$ | 0.65 |
| 5 | $y = -15.8 + 11.7x$ | 0.79 |
| 6 | $y = -35.9 + 24.5x$ | 0.72 |
| 7 | $y = -52.2 + 30.8x$ | 0.71 |
| 8 | $y = -93.4 + 50.2x$ | 0.70 |

Note: y = suspended solids (mg/l)
 x = log algal density
 $y = a + bx$

Algae

Algae, are classified partially according to their color. The blue-green algae, which include about 15 . . species, are so named because in addition to chlorophylls, they contain phycocyanin which gives them a blue to dark-green tint. A red pigment is sometimes also present,, They may be autotrophic or heterotrophic, are widely distributed, and occur in varied habitats. When they occur in massive numbers (a bloom), they are usually found at the water surface. They are more frequently found in lakes and ponds than in the running water of streams.

The green algae, including about 700 species, usually contain one major group of pigments, the chlorophylls, and most are autotrophic. Although a number live in salt water, the group as a whole is more characteristic of fresh water. They may be either free-floating or attached; if numerous, they give a green cast to the water.

Somewhat between blue-green and green algae are the diatoms, which are characterized by the presence of green, yellow, or brown pigments associated with the chlorophylls, depending on their life cycle stage. Diatoms vary in

color from brown to green,, Diatoms include about 16, 000 species and are the most dominant algae in Illinois running water.

In several divisions of algae, including some green algae, there are species known as flagellates, which are equipped with flagella (whiplike organs that make mobility possible). Flagellates are motile, may be either autotrophic or heterotrophic, and are most commonly found in organically enriched waters.

Desmids belong to a subgroup of green algae. There are numerous species of desmids, and they are usually associated with lakes and ponds.

During the period of study on Horseshoe Lake, 70 algal species were recovered from 152 samples. The collections included 6 genera and 10 species of blue-green algae, 1 . genera and 15 species of green algae, 15 genera and 36 species of diatoms, 5 genera and 7 species of flagellates, and 2 genera and 2 species of desmids.

The average composition for each algal type, based on algal density, is shown in table 13. With the exception of station 1, blue-green algae were the most common in Horseshoe Lake. For the 2-week period from July 18 to August 3 blue green algae made up 70 to 80 percent of the population at station 1, but thereafter green algae (consisting almost solely of *Crucigenia rectangularis*, which reached extraordinary bloom porportions from August 15 to November 16) were dominant at that station. *C. rectangularis* was initially recovered at a density of 68,000 counts per milliliter (cts/ml), reached a peak of 190,000 cts/ml on September 14, and finally bottomed out at 9000 cts/ml.

There was a distinct pattern in the development of the blue-green algae population. *Oscillatoria angustissima* was recovered in bloom proportions at stations 4, 5, 6, 7, and 8 on May 25, the first day of sampling. *Aphanisomenon flos-aquae* was recovered in bloom porportions at stations 7 and 8 during the next sampling day, June 8. Two weeks later *Anabaena spiroides* became pre-dominant, coexisting with *A. flos-aquae*, also in bloom proportions. These two blue-greens dominated algal populations at all stations except station 1 thereafter until August 3. On that date *A. spiroides* was not recovered

Table 13. Percent Composition of Algal Types Based on Algal Density

| Station | Average | | | | |
|---------|------------|-------|---------|-------------|---------|
| | Blue-green | Green | Diatoms | Flagellates | Desmids |
| 1 | 17.6 | 47.0 | 20.0 | 11.6 | 4.4 |
| 2 | 36.9 | 23.5 | 32.8 | 3.6 | 3.2 |
| 3 | 42.5 | 35.7 | 18.3 | 3.3 | 0.2 |
| 4 | 48.2 | 5.8 | 33.2 | 12.8 | 0.0 |
| 5 | 63.5 | 10.0 | 24.3 | 2.1 | 0.1 |
| 6 | 68.6 | 3.3 | 20.4 | 7.3 | 0.4 |
| 7 | 76.7 | 2.6 | 11.6 | 9.1 | 0.0 |
| 8 | 85.7 | 4.7 | 9.6 | 0.0 | 0.0 |

and thus *A. flos-aquae* was the dominant algae at all stations except station 1 for the next 7 weeks,, At the end of that period (November 16) *O. angustissima* reappeared and *A. flos-aquae* was not recovered. Algal densities were minimal thereafter until the end of the study period,,

Other green algae that occasionally pulsed besides *C. vectangulavis* include *Scenedesmus dimorphus*, *Ulothrix zonata*, *Pediastrum duplex*, and *Chlorella ellipsoidea*.

As shown in table 13, diatoms were second in order of importance. The most frequently occurring specics in terms of density were *Synedra acue* and *Melosira granulata*. Flagellates were of minor importance in the lake with *Euglena spp.* being the most prevalent.

The total algal densities recovered at each station for each sampling period are set forth in table 14. Blue-greens were the major contributor to these algal populations during the period from mid-July to mid-October. An exception was station 1, as noted earlier, probably due to its very shallow depth during this period (see figure 7). Another exception was station 8, where blue-greens ranged from 65 to 100 percent of the total algal population during the entire period of sampling from May 25, 1978, to January 23, 1979.

Table 14. Total Algal Counts per Milliliter of Water
(May 1978-January 1979)

| Date | Period | Station | | | | | | | |
|-----------|--------|---------|--------|--------|---------|--------|--------|---------|---------|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 5/24-25 | 1 | 68,302 | 18,427 | 16,537 | 28,612 | 55,860 | 31,290 | 21,315 | 24,202 |
| 6/7-8 | 2 | 19,162 | 20,160 | 720 | 800 | 7,665 | 6,772 | 19,897 | 29,872 |
| 6/21-22 | 3 | 22,995 | 21,945 | 19,635 | 21,052 | 32,550 | 38,272 | 68,407 | 48,720 |
| 7/5-6 | 4 | 22,050 | 21,840 | 19,582 | 30,502 | 44,415 | 55,912 | 55,282 | 47,880 |
| 7/18-19 | 5 | 10,447 | 12,232 | 7,822 | 21,105 | 29,925 | 38,745 | 40,057 | 37,747 |
| 8/2-3 | 6 | 20,790 | 17,482 | 13,807 | 22,417 | 48,037 | 52,185 | 59,167 | 39,322 |
| 8/15-16 | 7 | 79,147 | 36,592 | 25,725 | 110,775 | 18,112 | 50,610 | 100,432 | 146,370 |
| 8/30-31 | 8 | 100,170 | 23,047 | 16,800 | 87,576 | 16,380 | 20,685 | 100,432 | 89,932 |
| 9/13-14 | 9 | 213,202 | 59,850 | 28,140 | 6,720 | 6,562 | 49,717 | 17,587 | 23,835 |
| 9/27-28 | 10 | 24,202 | 46,725 | 20,370 | 8,925 | 7,140 | 37,117 | 17,797 | 15,855 |
| 10/11-12 | 11 | 13,440 | 17,062 | NS* | 7,402 | 6,667 | 22,627 | 11,970 | 8,452 |
| 10/25-26 | 12 | 21,157 | 8,032 | 7,455 | 7,507 | 7,875 | 5,932 | 14,595 | 10,920 |
| 11/15-16 | 13 | 14,280 | 4,830 | 3,937 | 6,930 | 4,252 | 3,412 | 10,552 | 6,142 |
| 11/29-30 | 14 | 388 | 252 | 48 | 149 | 262 | 79 | 128 | 86 |
| 12/13-14 | 15 | 203 | 88 | 75 | 54 | 92 | 25 | 67 | 63 |
| 1/8-9 | 16 | 144 | 218 | 44 | 1,016 | 79 | 52 | 33 | 39 |
| 1/22-23 | 17 | 81 | 33 | NS* | 56 | 44 | 37 | 254 | 69 |
| Geom mean | | 9148 | 5799 | 3834 | 4980 | 4661 | 5428 | 7838 | 6672 |

* NS = no sample

The significant influences of algae in the lake on water transparency and corresponding suspended solids and turbidity have been documented earlier,, Algal densities of the magnitude existing in Horseshoe Lake can also have a modifying influence on the water chemistry of the lake, particularly pH and alkalinity,, These relationships will be discussed in the following section,, At this time it is reasonable to conclude that the nature and magnitude of algal populations in the lake are singular characteristics that set it apart from most, if not all, impoundments used extensively for recreation purposes in Illinois.

Alkalinity and pH

The alkalinity of natural water is governed to a large extent by the geochemistry of the watershed. For Illinois conditions it consists mainly of three carbonic species. They are carbonic acid (H_2CO_3), bicarbonate (HCO_3^-) and carbonate ($CO_3^{=}$). The carbonic acid component is sometimes considered the carbon dioxide (CO_2) species. The three carbonic species are in equilibrium in stream and lake waters, and the relative concentration of each is a function of hydrogen ion (H^+) concentration. At a pH below 5 only H_2CO_3 is of quantitative importance, at a pH between 7 and 9 the HCO_3^- is of greatest significance, and at a pH above 9.5 the $CO_3^{=}$ species predominates.

In most surface waters in Illinois the total alkalinity is predominantly in the form of bicarbonate,, The dissociation of carbonic acid contributes to its formation as follows:

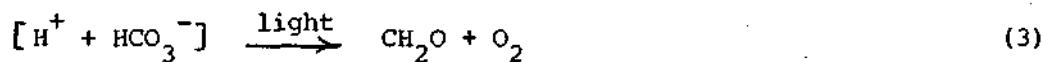


When pH exceeds 9, the carbonate ion is formed in the following way:



Under these conditions the $CO_3^{=}$ often precipitates and a loss of total alkalinity occurs.

During the process of photosynthesis algae derive their source of carbon from HCO_3^- in midwestern waters. The process may be expressed as:



Here the alkalinity, in the form of bicarbonates, is used to produce new cellular material (CH_2O) and dissolved oxygen (O_2). During the process the alkalinity in the water is reduced, and the dissolved oxygen and pH of the water increase.

The means and ranges of total alkalinity as $CaCO_3$ in Horseshoe Lake are presented in table 15.

These mean values are generally higher than observed in Rend and Cedar Lakes in southern Illinois (Illinois State Water Survey, 1978; Roseboom et al., 1978) but lower than lakes in central Illinois (Roseboom et al., 1979a). The range of values suggests the influence of biological activity, namely algae.

Table 15. Total Alkalinity
(Milligrams per liter)

| <i>Station</i> | <i>Mean</i> | <i>Range</i> |
|----------------|-------------|--------------|
| 1 | 84 | 48-129 |
| 2 | 93 | 39-166 |
| 3 | 127 | 90.-147 |
| 4 | 114 | 50-174 |
| 5 | 101 | 47-156 |
| 6 | 99 | 55-195 |
| 7 | 90 | 39-114 |
| 8 | 93 | 57-174 |
| 9 | 98 | 44-164 |

A regression analysis was performed to assess the relationship of alkalinity as a function of algal densities. A summary of results is given in table 16. There is a significant inverse relationship at the 99 percent confidence level for stations 2, 5, 6, 7, and 8. The correlation for these stations indicates that 57 to 71 percent of the variation in alkalinity at these stations was due to algal density. Similar relationships for stations 3 and 4 were not as strong. As with other water quality characteristics, the influence of effluent discharges and Nameoki Ditch at these two stations modifies the influence of algae-associated mediations.

This is illustrated to some extent in figure 14, where the concentrations of alkalinity of similar stations are depicted temporally. Very little fluctuation occurred at station 3, the site of the lowest mean algal densities, emphasizing that some compensation for algal influence is being applied by effluents from Granite City Steel. On the other hand, the erratic pattern for station 4 is difficult to assess. For stations 2, 5, 6, 7, and 8, however, the occurrence of the lower values of alkalinity is concurrent with the "algal bloom season" from mid-July to mid-October. An examination of figure 14 permits some speculation as to the probable value of alkalinity in the lake in the absence of algal growth. It is in the order of 12 . mg/1.

The pH unit is an expression of the hydrogen ion (H) concentration in water. It is commonly used to designate the intensity of acid and alkaline conditions in water. The mechanism causing the pH to increase during summer months in Illinois impoundments has been described in equation 3,

In most Illinois waters pH ranges from 7 to 9. Values of pH significantly above 8. . in Illinois waters are suggestive of biological activity. The ranges observed for the waters of Horseshoe Lake were:

| <i>Station</i> | <i>Range</i> | <i>Station</i> | <i>Range</i> |
|----------------|--------------|----------------|--------------|
| 1 | 7.6-10.4 | 6 | 6.7-10.4 |
| 2 | 7.3-9.9 | 7 | 7.7-10.2 |
| 3 | 6.9-8.5 | 8 | 7.4-9.8 |
| 4 | 7.2-9.2 | 9 | 7.4-9.5 |
| 5 | 7.0-9.5 | | |

Table 16. Alkalinity vs Log Algal Density

| Station | Equation of best fit | r |
|---------|----------------------|-------|
| 3 | $y = 147.3 - 5.3x$ | -0.38 |
| 4 | $y = 165.4 - 13.0x$ | -0.38 |
| 2 | $y = 194.7 - 27.6x$ | -0.75 |
| 5 | $y = 189.2 - 24.1x$ | -0.84 |
| 6 | $y = 189.1 - 24.3x$ | -0.80 |
| 7 | $y = 208.5 - 30.7x$ | -0.84 |
| 8 | $y = 187.9 - 24.8x$ | -0.83 |

Note: y = alkalinity as CaCO_3 (mg/l)
 x = log algal density
 $y = a + bx$

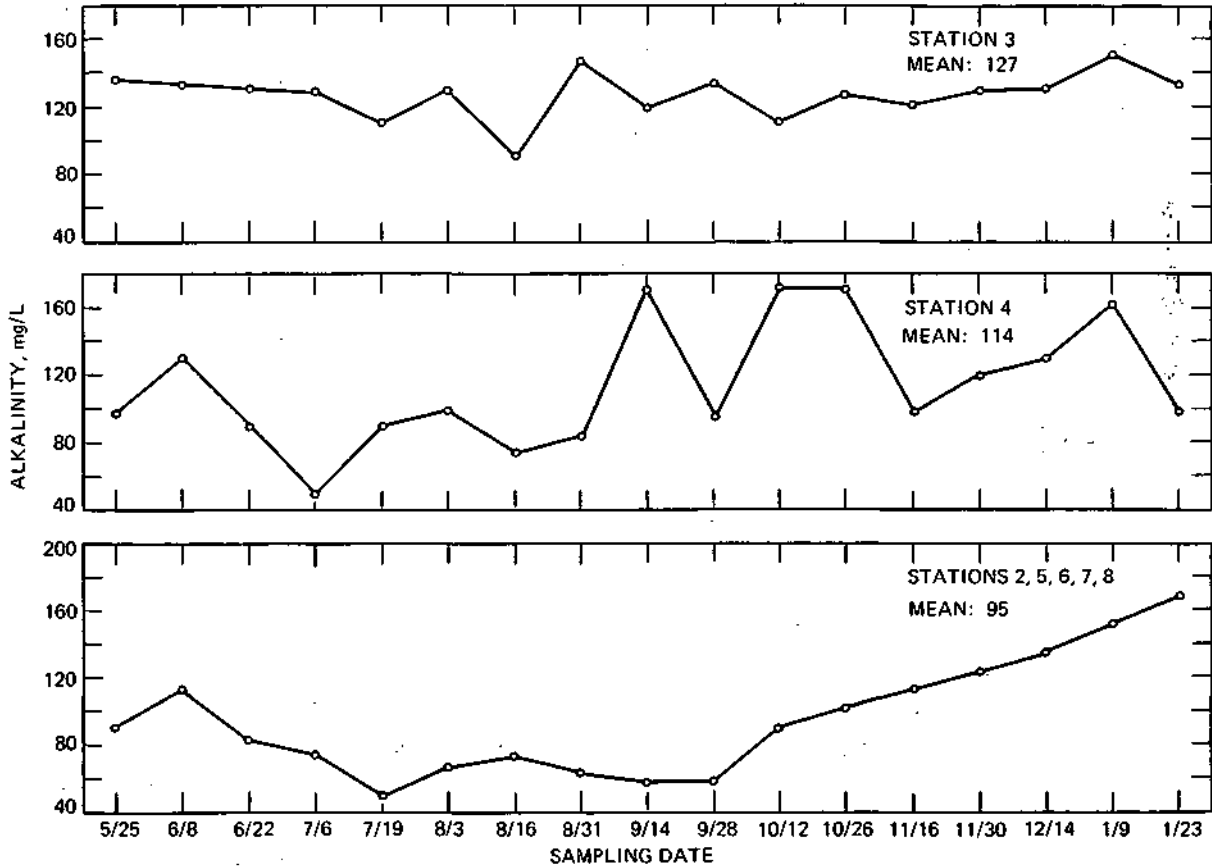


Figure 14. Alkalinity, Horseshoe Lake

The statistical relationships of pH as a function of algal density, developed from linear regression, are summarized in table 17. Unlike the rather weak relationship between alkalinity and algal density at station 3, the relationship between pH and algal density at that station was highly significant at a level of confidence of 99 percent. This indicates that the alkalinity of the effluent discharges near the station is of sufficient magnitude to compensate for any natural loss of alkalinity due to algal productivity, but that algal productivity, though less than at other stations, is influential within the narrow range of pH changes (6.9 - 8.5) occurring at the station. Other stations - notably 2, 6, 7, and 8 - have ranges of pH in the order of 7.3 to 10.0. The temporal variations in pH based on the grouping of stations in table 17 are shown in figure 15. The pattern of pH changes at station 4 is clear in contrast to the depiction of alkalinity concentrations at that station shown in figure 14. However only 3 . percent of the variations in pH at that station can, with 95 percent confidence, be attributed to algae densities. At other stations about 5 . to 77 percent of variations in pH can be laid to algal densities with 99 percent confidence. On the basis of observations in other Illinois impoundments with similar mineral characteristics to those in Horseshoe Lake, it is probable that the normal range for that lake without algal influence is 7.5 to 8.2. The shaded areas in figure 15 indicate departures from that speculative range, which (with some tentativeness regarding station 4) are considered algal mediated.

Ammonia-Nitrogen and Phosphorus

The basic nutrients governing biological activity in impounded water are nitrogen and phosphorus. Nitrogen occurs in the aquatic environment in several important forms. Those forms of primary interest in lake waters include organic nitrogen, inorganic nitrate, and ammonia. For this study only total ammonia-nitrogen determinations were performed. The various fractions and forms of phosphorus in Illinois waters have been reported by Sullivan and Hullinger (1969). In this study only total and dissolved phosphorus were examined. Total phosphorus includes particulate and dissolved phosphorus.. Dissolved phosphorus is the form more readily available for biological uptake.

Ammonia-nitrogen can stimulate algal growth, depress dissolved oxygen through the process of nitrification, and become toxic to aquatic life. Current rules and regulations administered by the Illinois Environmental Protection Agency (Illinois Water Pollution Control Board, June 1979) stipulate a limit of 2.5 mg/1 total ammonia-nitrogen in Illinois waters during April to October, with up to 4. . mg/1 permitted during November to March. The concentrations of total ammonia-nitrogen observed in Horseshoe Lake are given in table 18.

Total ammonia-nitrogen concentrations at the surface of Illinois impoundments rarely exceed 0.5 mg/1, and the range of the *means* is generally . . . 5 to . .2 . . High ammonia concentrations have been observed in lake water where a point discharge significantly affects its water quality. This is the case for Horseshoe Lake. Although concentrations of ammonia in the lake did not exceed limits specified by the rules and regulations (except during one sampling period at station 2), the influence of the effluent discharge in the

Table 17. pH vs Log Algal Density

| Station | Equation of best fit | r |
|---------|----------------------|------|
| 2 | $y = 6.6 + 0.55x$ | 0.68 |
| 3 | $y = 6.6 + 0.34x$ | 0.83 |
| 5 | $y = 6.5 + 0.51x$ | 0.86 |
| 4 | $y = 7.1 + 0.32x$ | 0.55 |
| 6 | $y = 6.2 + 0.68x$ | 0.88 |
| 7 | $y = 7.0 + 0.53x$ | 0.78 |
| 8 | $y = 7.0 + 0.47x$ | 0.81 |

Note: $y = \text{pH (units)}$
 $x = \text{log algal density}$
 $y = a + bx$

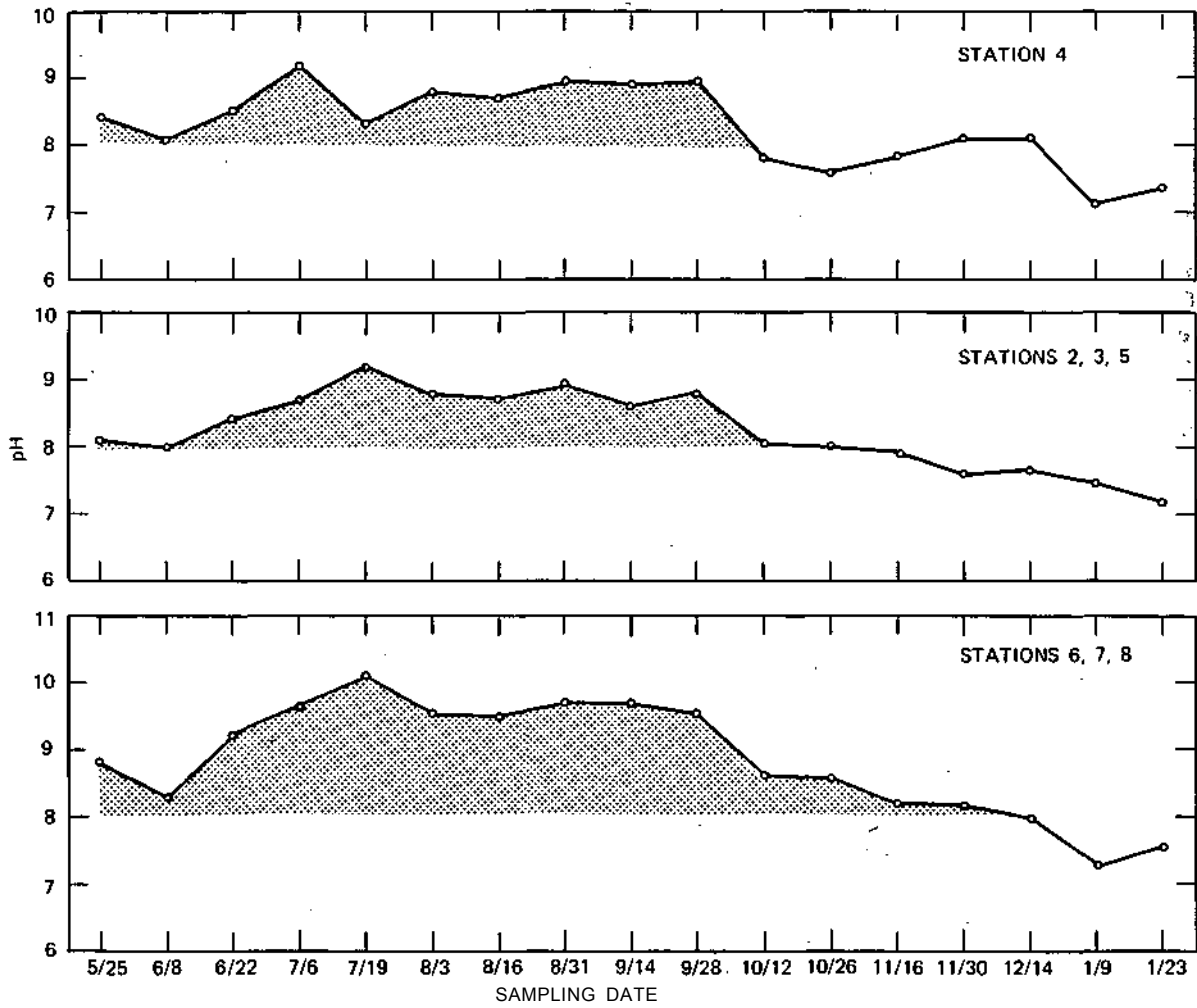


Figure 15, pH units, Horseshoe Lake

Table 18. Total Ammonia-Nitrogen
(Milligrams per liter)

| Date | Station | | | | | | | | |
|-------|---------|------|------|------|------|------|------|------|------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 5/25 | 0.02 | 0.38 | 0.33 | 0.25 | 0.12 | 0.07 | 0.07 | 0.04 | 0.05 |
| 6/8 | 0.02 | 2.19 | 0.84 | 1.53 | 1.54 | 0.85 | 1.13 | 1.77 | 1.73 |
| 6/22 | 0.16 | 0.79 | 0.62 | 0.19 | 0.24 | 0.19 | 0.11 | 0.12 | 0.27 |
| 7/6 | 0.00 | 0.10 | 0.82 | 0.15 | 0.12 | 0.20 | 0.14 | 0.14 | 0.19 |
| 7/19 | 0.07 | 0.16 | 0.34 | 0.37 | 0.09 | 0.25 | 0.19 | 0.12 | 0.22 |
| 8/3 | 0.01 | 0.09 | 0.39 | 0.11 | 0.19 | 0.05 | 0.05 | 0.05 | 0.02 |
| 8/16 | 0.11 | 0.03 | 1.58 | 0.21 | 0.28 | 0.10 | 0.11 | Tr | Tr |
| 8/31 | 0.24 | 0.07 | 0.16 | 0.21 | 0.53 | 0.15 | 0.04 | 0.04 | 0.47 |
| 9/14 | 0.48 | 0.14 | 0.22 | 0.20 | 0.27 | 0.21 | 0.19 | 0.30 | 0.50 |
| 9/28 | 0.02 | 0.04 | 0.66 | 0.52 | 0.30 | 0.02 | 0.05 | 0.02 | 0.69 |
| 10/12 | 0.04 | 0.35 | 0.35 | 0.34 | 0.31 | 0.26 | 0.47 | 0.12 | 0.88 |
| 10/26 | 0.12 | 0.83 | 0.68 | 0.47 | 0.72 | 0.64 | 0.66 | 0.50 | 0.57 |
| 11/16 | 0.24 | 1.63 | 0.81 | 0.58 | 0.97 | 0.64 | 0.68 | 0.56 | 0.66 |
| 11/30 | 0.35 | 1.25 | 0.61 | 0.69 | 0.99 | 0.78 | 0.71 | 0.88 | 0.88 |
| 12/14 | 0.25 | 1.00 | 0.68 | 1.07 | 0.84 | 0.49 | 0.73 | 0.78 | 0.76 |
| 1/9 | 0.17 | 0.93 | 0.89 | 1.07 | 0.79 | 0.19 | 0.48 | 0.85 | 0.76 |
| 1/23 | 0.68 | 1.46 | 0.83 | | 1.34 | 0.66 | 1.27 | 1.20 | 1.03 |
| Mean | 0.18 | 0.67 | 0.64 | 0.50 | 0.57 | 0.34 | 0.42 | 0.42 | 0.57 |

vicinity of station 4 is the governing factor for the lake's ammonia content,, The fact that total ammonia-nitrogen levels are usually less than that required by existing regulations should not be a source of comfort. Studies performed by Roseboom and Richey (1977) examined the toxicity of total ammonia-nitrogen to bluegill, bass, and channel catfish. They concluded that a *un-ionized* ammonia-nitrogen concentration of 0.04 mg/l should not be exceeded for the protection of the fishes investigated. The un-ionized ammonia-nitrogen fraction of the total ammonia-nitrogen is a function of pH and temperature. For the temperatures and pH ranges observed in Horseshoe Lake the total ammonia-nitrogen concentration should not exceed an average of 0.12 mg/l during the period June through September nor a maximum of 1.0 mg/l at any other time if game fish, particularly bluegill, are to be protected.

The Water Pollution Control Board (May, 1979) has stipulated that "After December 31, 1983 phosphorus as P shall not exceed 0.05 mg/l in any reservoir or lake with a surface area of 20 acres or more, or in any stream at the point where it enters any such reservoir or lake." It is not unusual for mean total phosphorus levels in Illinois streams to exceed 0.1 mg/l. Where the watershed drainage to streams is predominantly rural, dissolved phosphorus concentrations vary from 25 to 35 percent of the total. Where treated domestic waste effluents contribute significantly to stream flow, the dissolved phosphorus is likely to represent 60 to 80 percent of the total phosphorus. The phosphorus levels in Illinois lakes at the water surface are less than those of their tributary streams. This is because most of the phosphorus entering lakes is in particulate form and it is reasonable to expect a major portion of it to settle to the bottom. In spite of this reduction it is not unusual for mean total phosphorus concentrations in Illinois lakes to exceed 0.05 mg/l.

The observations for total and dissolved phosphorus concentrations in Horseshoe Lake are given in tables 19 and 20, respectively,,

With the exception of two high values (2.40 and 2.39) that may be artifacts and were not included in computing means, the observed mean values and ranges are comparable to those observed in other highly eutrophic lakes in Illinois. For example, the mean total phosphorus concentrations in the Fox Chain of Lakes ranged from 0.12 to 0.33 mg/l. The grouping of stations 2, 3, and 5 and stations 4, 6, 7, and 8 appears justified on the basis of their respective values for total phosphorus mean concentrations and ranges. It is even more logical if the ratios of the mean dissolved phosphorus to the mean total phosphorus are examined. They are as follows:

| <i>Station</i> | <i>DP:TP</i> | <i>Station</i> | <i>DP:TP</i> |
|----------------|--------------|----------------|--------------|
| 2 | 0.25 | 4 | 0.13 |
| 3 | 0.28 | 6 | 0.08 |
| 5 | 0.23 | 7 | 0.13 |
| | | 8 | 0.13 |

This shows that on the average 72 to 77 percent of the total phosphorus at stations 2, 3, and 5 was in particulate form, whereas 87 to 92 percent of the total phosphorus at stations 4, 6, 7, and 8 was in particulate form. Presumably the particulate material was algae and suspended bottom muds.

Table 19. Total Phosphorus
(Milligrams per liter)

| <i>Date</i> | <i>Station</i> | | | | | | | | |
|-------------|----------------|----------|----------|----------|----------|----------|----------|----------|----------|
| | <i>7</i> | <i>2</i> | <i>3</i> | <i>4</i> | <i>5</i> | <i>6</i> | <i>7</i> | <i>8</i> | <i>9</i> |
| 5/25 | 0.60 | 0.11 | 0.11 | 0.25 | 0.09 | 0.35 | 0.40 | 0.22 | 0.35 |
| 6/8 | 1.04 | 0.20 | 0.12 | 0.19 | 0.20 | 0.32 | 0.39 | 0.32 | 0.35 |
| 6/22 | 0.56 | 0.13 | 0.13 | 0.37 | 0.14 | 0.33 | 0.38 | 0.33 | 0.34 |
| 7/6 | 0.85 | 0.10 | 0.08 | 0.40 | 0.20 | 0.37 | 0.29 | 0.38 | 0.70 |
| 7/19 | 0.99 | 0.16 | 0.10 | 0.21 | 0.23 | 0.42 | 0.36 | 0.42 | 0.51 |
| 8/3 | 0.96 | 0.25 | 0.07 | 0.21 | 0.07 | 0.30 | 0.33 | 0.33 | 0.37 |
| 8/16 | 1.33 | 0.18 | 0.08 | 0.42 | 0.16 | 0.36 | 0.37 | 0.47 | 0.43 |
| 8/31 | 2.01 | 0.17 | 0.08 | 0.44 | 0.11 | 0.24 | 0.23 | 0.30 | 0.35 |
| 9/14 | 3.17 | 0.18 | 2.40* | 0.32 | 0.24 | 0.30 | 0.28 | 0.28 | 1.35* |
| 9/28 | 1.14 | 0.15 | 0.14 | 0.19 | 0.13 | 0.18 | 0.17 | 0.23 | 0.29 |
| 10/12 | 1.59 | 0.08 | 0.05 | 0.10 | 0.12 | 0.13 | 0.12 | 0.17 | 0.16 |
| 10/26 | 0.99 | 0.08 | 0.06 | 0.11 | 0.11 | 0.17 | 0.14 | 0.15 | 0.27 |
| 11/16 | 0.35 | 0.04 | 0.03 | 0.18 | 0.10 | 0.11 | 0.12 | 0.10 | 0.14 |
| 11/30 | 0.20 | 0.06 | 0.03 | 0.08 | 0.09 | 0.12 | 0.10 | 0.07 | 0.09 |
| 12/14 | 0.12 | 0.02 | 0.02 | 0.07 | 0.06 | 0.11 | 0.06 | 0.07 | 0.06 |
| 1/9 | 0.11 | 0.03 | 0.03 | 0.14 | 0.04 | 0.18 | 0.12 | 0.06 | 0.04 |
| 1/23 | 0.10 | 0.02 | 0.02 | 0.18 | 0.04 | 0.12 | 0.11 | 0.03 | 0.03 |
| Mean | 0.95 | 0.12 | 0.07 | 0.23 | 0.13 | 0.24 | 0.23 | 0.23 | 0.28 |

* Questionable, not included in computations

Table 20. Dissolved Phosphorus
(Milligrams per liter)

| Date | Station | | | | | | | | |
|-------|---------|------|-------|------|------|------|------|------|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 5/25 | 0.08 | Tr | Tr | Tr | 0.06 | 0.02 | 0.00 | 0.02 | 0.03 |
| 6/8 | 0.09 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.03 | 0.02 | 0.02 |
| 6/22 | 0.15 | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.06 | 0.03 | 0.02 |
| 7/6 | 0.10 | 0.02 | 0.05 | 0.02 | 0.06 | 0.01 | 0.03 | 0.02 | 0.01 |
| 7/19 | 0.15 | 0.01 | 0.01 | 0.03 | 0.01 | 0.02 | 0.01 | 0.03 | 0.03 |
| 8/3 | 0.14 | 0.05 | 0.03 | 0.05 | 0.05 | 0.07 | 0.05 | 0.03 | 0.05 |
| 8/16 | 0.13 | 0.01 | Tr | 0.02 | 0.01 | 0.01 | 0.02 | 0.03 | 0.01 |
| 8/31 | 0.14 | 0.02 | 0.03 | 0.06 | 0.04 | 0.07 | 0.07 | 0.11 | 0.05 |
| 9/14 | 1.93 | 0.10 | 2.39* | 0.06 | 0.06 | 0.04 | 0.04 | 0.08 | 0.81* |
| 9/28 | 0.11 | 0.02 | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 |
| 10/12 | 0.05 | 0.06 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.04 | 0.01 |
| 10/26 | 0.09 | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 |
| 11/16 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.03 | 0.02 |
| 11/30 | 0.03 | 0.04 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 12/14 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.05 | 0.01 | 0.02 |
| 1/9 | 0.02 | 0.01 | 0.03 | 0.02 | 0.02 | 0.04 | 0.03 | 0.01 | 0.02 |
| 1/23 | 0.05 | 0.01 | 0.02 | 0.04 | 0.02 | 0.02 | 0.02 | 0.03 | 0.02 |
| Mean | 0.19 | 0.03 | 0.02 | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.02 |

* Questionable, not included in computations

This grouping of stations once again shows the modifying influence of effluent discharges in the vicinity of station 3, where the lowest mean value of 0.07 mg/1 total phosphorus was observed.

Mineral Quality

In natural waters the total dissolved solids consist mainly of carbonates, bicarbonates, sulfates, chlorides, phosphates, and nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese, and other substances. The constituent composition of these minerals is usually dependent upon the geochemistry of the watershed and groundwater resources. All these salts in solution change the physical and chemical nature of the water and exert osmotic pressure. Some have physiological as well as toxic effects, and when mixed they behave differently than when they occur separately. During this study analyses for total dissolved solids were performed on all samples. On one date, January 8, 1979, additional analyses were undertaken for hardness, nitrate-nitrogen, fluoride, chloride, sulfate, potassium, sodium, calcium, and magnesium in water at each station.

The results for total dissolved solids in Horseshoe Lake are given in table 21. The waters of the lake are highly mineralized with station means varying from 532 to 711 mg/1. With the exception of strip mine lakes, the waters of Horseshoe Lake are the most highly mineralized lake water the Water Survey has investigated. Although the mineral characteristics of effluent discharges in the vicinity of station 3 were not assessed, it is apparent from

Table 21. Total Dissolved Solids
(Milligrams per liter)

| Date | Station | | | | | | | | |
|-------|---------|-----|-----|-----|-----|-----|-----|-----|-----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 5/25 | 552 | 723 | 714 | 343 | 494 | 359 | 401 | 441 | 450 |
| 6/8 | 319 | 587 | 778 | 550 | 509 | 418 | 436 | 515 | 511 |
| 6/21 | 388 | 620 | 760 | 522 | 595 | 585 | 475 | 532 | 537 |
| 7/6 | 345 | 572 | 718 | 495 | 516 | 417 | 479 | 511 | 606 |
| 7/19 | 364 | 556 | 615 | 673 | 539 | 480 | 503 | 558 | |
| 8/3 | 387 | 565 | 757 | 529 | 588 | 458 | 575 | 548 | 520 |
| 8/16 | 441 | 641 | 813 | 622 | 660 | 602 | 569 | 542 | 645 |
| 8/31 | 472 | 700 | 701 | 551 | 629 | 575 | 543 | 620 | 640 |
| 9/14 | 648 | 648 | 587 | 692 | 683 | 582 | 623 | 615 | 638 |
| 9/28 | 672 | 664 | 733 | 652 | 599 | 622 | 591 | 625 | 633 |
| 10/12 | 721 | 687 | 687 | 653 | 663 | 699 | 652 | 660 | 684 |
| 10/26 | 705 | 724 | 653 | 543 | 633 | 626 | 631 | 616 | 647 |
| 11/16 | 620 | 687 | 703 | 462 | 641 | 600 | 585 | 600 | 616 |
| 11/30 | 587 | 691 | 758 | 629 | 618 | 615 | 592 | 622 | 616 |
| 12/14 | 540 | 668 | 704 | 530 | 611 | 498 | 597 | 611 | 606 |
| 1/9 | 649 | 778 | 685 | 606 | 668 | 563 | 643 | 663 | 691 |
| 1/23 | 638 | 739 | 724 | 752 | 681 | 547 | 649 | 663 | 693 |
| Mean | 532 | 662 | 711 | 577 | 607 | 544 | 561 | 585 | 608 |

the mineral quality at that station -- the highest of all stations -- that the effluent governs the lake's mineral quality,,

Some insight into the makeup of the total dissolved solids in the lakes is offered by table 22. The sample, having been collected during cold water conditions, is representative of the lake water without significant biological influence,, The water is very hard, ranging from 353 to 416 mg/1 as CaCO₃. It is surprising that this hardness exists considerably in excess of alkalinity con-

Table 22. Mineral Constituents and Concentrations
in Samples Collected January 8, 1979

| Constituents | (Milligrams per liter) | | | | | | |
|-----------------------------|------------------------|-----|-----|-----|-----|-----|-----|
| | Station | | | | | | |
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Dissolved solids | 778 | 685 | 606 | 668 | 563 | 643 | 663 |
| Hardness, CaCO ₃ | 416 | 411 | 353 | 361 | 366 | 388 | 387 |
| Nitrate-N | 1.8 | 2.0 | 0.7 | 1.5 | 0.2 | 0.5 | 1.2 |
| Fluoride | 2.0 | 1.5 | 0.7 | 1.6 | 0.4 | 1.1 | 1.7 |
| Chloride | 166 | 145 | 171 | 145 | 124 | 124 | 142 |
| Sulfate | 142 | 141 | 82 | 137 | 148 | 134 | 134 |
| Potassium | 27 | 12 | 7 | 19 | 5 | 13 | 21 |
| Sodium | 50 | 44 | 70 | 50 | 28 | 39 | 48 |
| Calcium | 108 | 110 | 102 | 100 | 100 | 105 | 105 |
| Magnesium | 25 | 24 | 13 | 19 | 17 | 25 | 22 |

centrations (mean range 84-127 mg/1 as CaCO₃), since most lakes in Illinois are characterized as "carbonate hardness" waters with alkalinity concentrations about equal to hardness. In Horseshoe Lake the hardness is "non-carbonate" with the prevailing anions being sulfate (SO₄²⁻) and chloride (Cl⁻) rather than bicarbonate (HCO₃⁻). The chloride content, ranging from 124 to 166 mg/1, is exceedingly high for Illinois lakes. Data regarding potassium and sodium content in Illinois surface waters are sparse. However, based solely on observations made on the tributary streams of Rend Lake (Illinois State Water Survey, 1978), where potassium concentrations averaged about 7 mg/1, the potassium content of the lake's water (5-27 mg/1) is relatively high. The average concentration of potassium in 12 strip mine lakes (Gibb and Evans, 1978) ranged from 2 to 9 mg/1.

The effect of the mineralized lake water on its aquatic inhabitants is not known. It is probable that acclimation does or will play a role in the perpetuation of those aquatic plants or animals introduced into the waters, but it should be pointed out that the maximum permissible concentration of 1000 mg/1 total dissolved solids established by the Illinois Water Pollution Control Board is not exceeded in the lake.

Heavy Metals

On three occasions the waters of Horseshoe Lake were examined for the heavy metals manganese, iron, cadmium, copper, lead, and zinc. No effort was made to separate the sample into its soluble and particulate fractions. Analyses were performed on the whole sample, and the results are reported as total concentrations.

Gross (1979) has performed a quantitative examination of the lake's bottom sediments for metal content, but published data regarding the heavy metal content of the waters of Illinois lakes are limited. Recent work by Gibb and Evans (1978) documented the content of the most commonly occurring heavy metals in 12 strip mine lakes.

The Illinois Pollution Control Board (IPCB) has established maximum permissible limits for concentrations of some heavy metals in surface waters. Those limits for the metals examined in the waters of Horseshoe Lake (in milligrams per liter) are:

| | | | |
|------------------------|-------------|---------------------|-------------|
| Total manganese | 1.00 | Total copper | 0.10 |
| Total iron | 2.00 | Total lead | 1.00 |
| Total cadmium | 0.15 | Total zinc | 1.00 |

When assessing the values of total metal concentrations in lake water, including soluble and particulate fractions, it is important to realize that shallow lakes occasionally exhibit higher concentrations at their water surfaces than do deep lakes because of the interchange between overlying water and the bottom sediments of shallow lakes such as Horseshoe Lake. Bottom sediments are the "sink" for heavy metals. During periods of stratification in deeper lakes when anaerobic conditions are created, heavy metals in the bottom sediments will solubilize and contribute to concentrations in the overlying water column. This happened in the deep hole (station 5) in the lake.

The results of sampling the waters of Horseshoe Lake for heavy metal concentrations are tabulated in table 23. Generally the concentrations are in compliance with the IPCB standards, but there are exceptions. In July total iron concentrations exceeded standards at the surface waters of stations 1, 4, 8, and 9. During that time suspended solids concentrations were 351, 162, 178, and 551 mg/l, respectively, at the stations. It is fair to conclude that excessive iron in the water column during this period is a function of suspended bottom sediment and is not an unusual occurrence for Illinois conditions. Higher than normal zinc concentrations at station 9 in July can be explained similarly.

The concentrations of manganese, iron, and copper in the bottom waters at station 5 exceeded the standards during July. This too is a function of bottom sediments during a period of stratification - also a common occurrence in Illinois impoundments.

Table 23. Heavy Metals in Water Column
(Milligrams per liter)

| | Station | | | | | | | | | | IPCB standard |
|-----------------------|---------|------|-------|-------|-------|-------|-------|------|-------|--------|------------------|
| | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 | 9 | |
| <i>July 6, 1978</i> | | | | | | | | | | | |
| Total manganese | 0.53 | 0.16 | 0.10 | 0.03 | 0.05 | 1.78* | 0.13 | 0.16 | 0.26 | 0.39 | 1.00 |
| Total iron | 6.34* | 0.61 | 1.70 | 3.29* | 0.85 | 2.25* | 1.69 | 2.00 | 4.35* | 10.34* | 2.00 |
| Total cadmium | ND | ND | 0.26* | 2.00* | 0.40* | 0.30* | 0.40* | ND | ND | 2.60* | 0.15 |
| Total copper | ND | ND | tr | ND | ND | 0.11* | ND | ND | ND | ND | 0.10 |
| Total lead | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 1.00 |
| Total zinc | 0.64 | 0.08 | 0.16 | 0.30 | 0.15 | 0.19 | 0.20 | 0.53 | 0.58 | 1.29* | 1.00 |
| <i>Sept. 28, 1978</i> | | | | | | | | | | | |
| Total manganese | 0.13 | 0.12 | 0.12 | 0.19 | 0.12 | 0.22 | 0.12 | 0.19 | 0.11 | 0.55 | 1.00 |
| Total iron | 0.81 | 0.60 | 0.88 | 1.92 | 0.44 | 0.94 | 0.68 | 0.68 | 1.20 | 1.18 | 2.00 |
| Total cadmium | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | 0.15 |
| Total copper | tr | tr | tr | tr | tr | tr | tr | tr | tr | tr | 0.10 |
| Total lead | 0.13 | 0.13 | 0.17 | 0.17 | 0.11 | 0.13 | 0.13 | 0.08 | 0.13 | 0.13 | 1.00 |
| Total zinc | 0.08 | 0.06 | 0.09 | 0.16 | 0.06 | 0.08 | 0.07 | 0.09 | 0.07 | 0.31 | 1.00 |
| <i>Jan. 9, 1979</i> | | | | | | | | | | | |
| Total manganese | 0.03 | 0.05 | 0.04 | 1.20* | 0.10 | 0.10 | 0.80 | 0.08 | 0.05 | 0.09 | 1.00 |
| Total iron | 0.27 | 0.20 | 0.43 | 0.54 | 0.37 | 0.44 | 0.37 | 0.44 | 0.24 | 0.37 | 2.00 |
| Total cadmium | 0.20 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.17* | 0.15 |
| Total copper | tr | tr | tr | tr | tr | 0.02 | tr | tr | tr | tr | 0.10 |
| Total lead | 0.06 | 0.06 | 0.10 | 0.10 | 0.07 | 0.08 | 0.07 | 0.10 | 0.06 | 0.07 | 1.00 |
| Total zinc | 0.05 | 0.06 | 0.09 | 0.07 | 0.10 | 0.09 | 0.06 | 0.05 | 0.06 | 0.05 | 1.00 |

* Non-compliance with IPCB standards

Note: ND = not detected; NS = no sample

The concentrations of total cadmium during the July sampling exceeded water quality standards at stations 3, 4, 5, 6, and 9. These conditions of non-compliance cannot be rationalized in terms of disturbed bottom sediments,, Unfortunately the samples collected in September were not examined for cadmium, thus limiting speculation regarding the frequency of such occurrences.

The range of values (mg/l) observed in strip mine lakes at mid-depth for the six heavy metals examined in Horseshoe Lake are:

| | | | |
|------------------------|-------------------|---------------------|------------------|
| Total manganese | 0.01--1.58 | Total copper | 0.01-0.08 |
| Total iron | 0.01--0.96 | Total lead | 0.00-0.17 |
| Total cadmium | 0.00--0.04 | Total zinc | 0.02-0.10 |

Comparing these values with those for the lake water indicates that, with the exception of copper and lead, the lake's metal content is generally higher than that of strip mine lakes. Concentrations of copper and lead are comparable.

Sediment Oxygen Demand

Sediment oxygen demand can be broadly defined as a demand imposed on the dissolved oxygen resources of overlying water by biological organisms (algae, macroinvertebrates, and microbes) and inorganic chemical oxidation reactions, all associated with bottom sediments. Measurements for SOD were performed on three separate occasions at stations 2, 3, 4, 7, and 8.

From an evaluation of the initial SOD measurements it became clear that the respiration of suspended algae trapped in the SOD chamber contributed greatly to field recorded dissolved oxygen uptake. This factor, which has not been important in other studies involving SOD assessments, required adjustments in SOD measurements. The results for a standard temperature of 25°C are given in table 24.

In terms of SOD the lake sediments can be broadly classified as moderately polluted to polluted. The sediments at station 3 had the lowest demand, while the highest demand was at station 7. Table 25 shows that the results are comparable with those of other shallow lakes in Illinois.

The top layer of the bottom sediments in Horseshoe Lake is basically unconsolidated and easily resuspended when disturbed,, A correlation between the percent solids of the sediment and the number of macroorganisms recovered indicates that the more compact sediments tend to harbor greater numbers of macroorganisms. A study of the sediment characteristics of Lake Meredosia (Lee et al., 1975), a lake physically similar to Horseshoe Lake, similarly indicated that watery sediment provides poor benthos substrate. As will be discussed later, the densities of macroinvertebrates recovered from the sediment of Horseshoe Lake were not large. It is reasonable to conclude that macroinvertebrates do not contribute measurably to SOD rates in the lake, and the low rates of SOD observed for the lake's disturbed sediment (Butts and Evans, 1979) suggest that chemical oxidation is not a major component of SOD either. On the basis of elimination it can be determined that the principal

Table 24. SOD Rates Corrected for Algal Respiration

| <i>Date (1978)</i> | <i>Station</i> | <i>Corrected SOD rate (g/m²/day) at 25°C</i> |
|--------------------|----------------|---|
| June 27-28 | 2 | 1.80 |
| | 3 | 2.14 |
| | 4 | 3.84 |
| | 7 | 4.36 |
| | 8 | 1.15 |
| August 30-31 | 2 | 3.92 |
| | 3 | 2.40 |
| | 4 | 2.50 |
| | 7 | 3.50 |
| | 8 | 3.96 |
| October 25-26 | 2 | 3.76 |
| | 3 | 2.46 |
| | 4 | 3.15 |
| | 7 | 3.48 |
| | 8 | 3.02 |

Table 25. SOD Rates in Some Illinois Lakes

| <i>Lake</i> | <i>SOD rate (g/m²/day) at 25°C</i> |
|---------------------|---|
| Depue | 2.59 |
| Meredosia station 4 | 4.74 |
| Meredosia station 5 | 3.85 |
| Meredosia station 9 | 2.83 |
| Fox | 3.44 |
| Nippersink | 8.32 |
| Horseshoe station 2 | 3.16 |
| Horseshoe station 3 | 2.33 |
| Horseshoe station 4 | 3.16 |
| Horseshoe station 7 | 3.78 |
| Horseshoe station 8 | 2.71 |

Note: Horseshoe Lake values are an average of 3 seasonal values adjusted for algal respiration.

factor responsible for the SOD rates is microbial activity.

The influence of the bottom sediments on the dissolved oxygen resources of the overlying water is demonstrated by a mathematical model derived from this phase of the lake study. The model indicates that the dissolved oxygen in the waters can be totally depleted in less than a week if the lake water is completely sealed by ice and snow during the winter.

Macroinvertebrates

The benthic macroinvertebrates recovered from the routine sampling of the bottom muds of Horseshoe Lake were dominated by true midge fly larvae (Chironomidae), phantom midge fly larvae (*Chaoborus*), and aquatic worms (Oligochaeta). These are the kinds of benthic organisms found in most of the mud-bottomed lakes and impoundments in Illinois,, They are all tolerant of organic pollution.

Chironomidae remain in the bottom sediments until pupation and the emergence of the adult fly. They have a hemoglobin-like blood pigment and special gills to extract sufficient oxygen even from nearly oxygen-depleted waters. The *Chaoborus* has air sacs that permit it to visit the surface waters at night to feed and renew its oxygen supplies; during the day, this organism burrows in the bottom sediments and may survive there in great numbers, even in the absence of oxygen. The Oligochaeta is confined to the bottom muds, preferring organically enriched muds, and is also capable of withstanding prolonged periods of low dissolved oxygen concentrations.

In typical Illinois mud-bottomed lakes, the benthos is dominated by Chironomidae in well oxygenated areas; by *Chaoborus* in deeper, usually thermally stratified, areas; and by Oligochaeta in organically enriched areas.

The results of the routine benthic sampling in Horseshoe Lake and comparisons with that at five other Illinois lakes are included in table 26.

Table 26. Benthic Macroinvertebrate Community Composition and Numbers per Square Meter in Horseshoe Lake and Five Other Lakes

| Lake | Average (no./m ²) | Percentage of total | | | | |
|-------------------|----------------------------------|---------------------|------------------|-------------|--------|----|
| | | Chironomidae | <i>Chaoborus</i> | Oligochaeta | Others | |
| Horseshoe station | 1 | 1006 | 59 | 1 | 30 | 10 |
| | 2 | 1281 | 29 | 65 | 6 | |
| | 3 | 377 | 46 | 25 | 29 | |
| | 4 | 589 | 30 | 16 | 54 | |
| | 5 | 907 | 3 | 93 | 4 | |
| | 6 | 851 | 59 | 15 | 26 | |
| | 7 | 944 | 48 | 27 | 25 | |
| | 8 | 1295 | 53 | 14 | 33 | |
| Average | 906 | 41 | 32 | 26 | 1 | |
| Rend Lake | 740 | 49 | 20 | 31 | | |
| Fox Lake | 110 | 73 | 27 | 0 | | |
| Ten Cent Lake | 463 | 25 | 32 | 16 | 27 | |
| Cedar Lake | 998 | 42 | 56 | 2 | | |
| Lake Catherine | 101 | 14 | 86 | 0 | | |

Note: Rend Lake data from Illinois State Water Survey, 1978; Fox Lake and Lake Catherine data from Kothandaraman et al., 1977; Ten Cent Lake data from Larimore et al., 1973; Cedar Lake data from Roseboom et al., 1978

The benthos at stations 1/3, 6, 7, and 8 were dominated by members of the family Chironomidae; the two deepest stations (station 2 and particularly station 5) were dominated by *Chaoborus*; and station 4 was dominated by Oligochaeta, perhaps resulting from organic enrichment from combined sewers with reported overflows into Nameoki Ditch. A more diverse benthic community was found at station 1 because of its shallowness and closeness to shore.

Rend Lake and Fox Lake are relatively shallow, wind-mixed lakes dominated by Chironomidae, while Cedar Lake and Lake Catherine are deeper, stratified lakes dominated by *Chaoborus*. Ten Cent Lake, a floodplain pool on the Kaskaskia River, appears to have a more balanced benthic community, perhaps due to the effects of transect sampling, in which shore areas are sampled along with the deeper areas of the lake.

Non-quantitative macroinvertebrate samples, collected near the shoreline with an aquatic dip net, yielded organisms not found during routine benthic sampling. Four genera of aquatic Hemiptera (waterbugs), two genera of Gastropoda (snails) and a genus of Coleoptera (beetles) were found only near shore. A member of the family Corixidae (water boatmen) (*Trichocorixa kanza*) was very abundant.

The mean number of individuals per square meter of all the routine benthic samples from Horseshoe Lake was 906. The lowest mean number of individuals was found at station 3 (377 indiv/m²) and the highest, at station 8 (1295 indiv/m). Horseshoe Lake compares favorably in benthic productivity with the other five mud-bottomed lakes considered for comparison.

Zooplankton

The population and relative dominance among species of zooplankton can be and often are largely determined by the food preference of planktivorous fish. It has been argued that the enrichment of a lake's waters directly affects the number and species distribution of zooplankton, but the generally accepted hypothesis is that the alteration brought about by enrichment directly affects the fish population, which in turn governs the character of the zooplankton population (Brooks, 1969).

Zooplankton is an integral part of the aquatic food chain. Since a viable population of cladocerans and copepods is an excellent source of nourishment for sight-feeding fishes, a healthy concentration of the somewhat large zooplankton in a lake is desirable.

Sample collections were made at stations 2, 3, 5, and 7 in Horseshoe Lake, and in 67 samples 19 species of zooplankton were recovered. All specimens were composed of Rotifera, cladocera, and Copepoda. Of the 7 species of Rotifera collected, the dominant species was *Branchionus havanaensis*; of the 4 species of cladocera collected, the *Bosmina longirostris* was dominant; and of the 8 species of Copepoda collected, the *Diaptomis pallidus* predominated. The average number (individuals per liter) of organisms collected per station and their composition was:

| | |
|-----------|------|
| Rotifera | 907 |
| Cladocera | 372 |
| Copepoda | 641 |
| Total | 1920 |

The copepod *D. pallidus*, although exhibiting some fluctuations, inhabited most stations during the entire period of sampling from May 25, 1978 to January 23, 1979. The small cladoceran *B. Zongirostvis* was markedly seasonal, with significant appearances only between May 25 and July 19. Except for the copepods, zooplankton organisms were not a viable population in the lake after mid-September. The most productive period was July,

The predominance of rotifers is not unexpected. Because of their small size they are relatively unavailable as a source of food for sight-feeding fishes (Larimore et al., 1973). The almost complete absence of large daphnia, such as *Daphnia putex* (see appendix F), and other large cladocerans can be accounted for by the selective predation by planktivorous fish which are abundant in the lake. Zooplankton thrive on small algal cells, bacteria, and particulate debris, but the blue-green algae, consisting of large colonies, cannot be used by true planktonic herbivores. In other words the zooplankton existing in Horseshoe Lake do little to crop the predominant algae,

Macrophytes

Although it was not an obligation of the study, a cursory examination was made of the extent and principal types of aquatic plants existing in Horseshoe Lake. The macrophytes were dominated by moist soil plants with little emergent vegetation. There was a lack of submerged plants, probably due to turbidity and flocculent bottom muds in the off-shore areas and to wave action combined with water level fluctuations in the near-shore areas.

The dominant emergent plant was arrowhead (*Sagittaria spp.*), which was found in numerous stands in wind-sheltered areas of the lake. In two areas, the Elm Slough bay area and the east shore north of the causeway to Walker's Island, American lotus (*Nelumbo lutea*) was the predominant emergent plant. Figure 16 is typical of the Elm Slough area. In marshes such as at the delta (see figure 17) cattails (*Typha spp.*) were prevalent.

Good growths of moist soil plants such as bulrush, nutgrasses, and smartweed inhabit the shoreline of the lake during low water levels. The view of the shoreline shown in figure 18 is typical. The subsequent flooding of these plants provides food and shelter for waterfowl.

In summary, the principal macrophytes casually observed in Horseshoe Lake were American lotus, arrowhead, bulrush, cattail, creeping water primrose, duckweed, millet, nutgrasses, and smartweed.

Unscheduled Observations

As part of routine sampling and subsequent analyses during the visit to the lake on January 22-23, 1979, residual chlorine was detected in four water

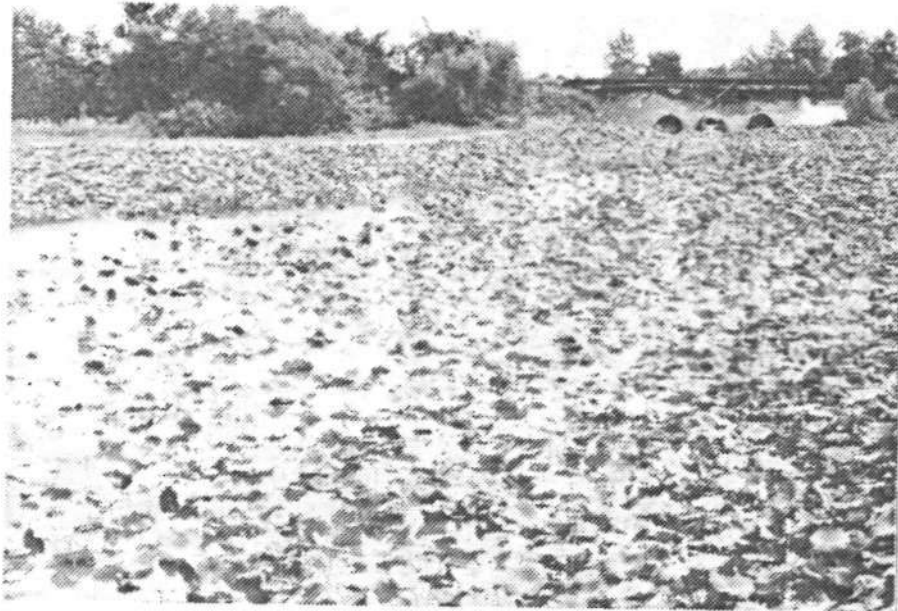


Figure 16. American lotus in the Elm Slough bay area



Figure 77, Delta area south of Walker's Island

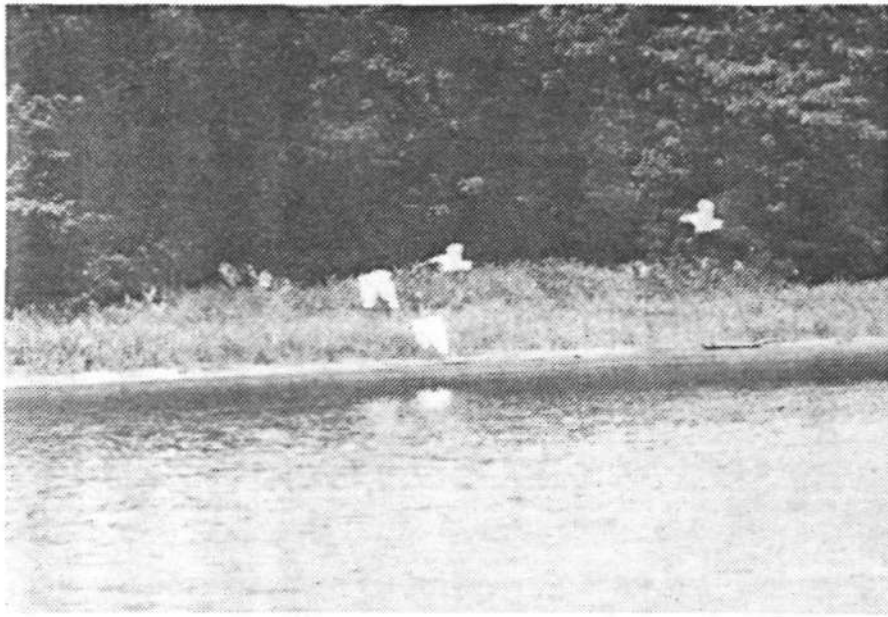


Figure 18. Herons in flight near station 7

samples. The samples were collected at stations 3, 4, 5t, and 5b, and the concentrations of chlorine in the samples were, respectively, 0.035, 0.26, 1.5, and 1.5 mg/l. The findings were reported to the IEPA.

Chlorine residual determinations were not performed routinely on the samples collected from Horseshoe Lake,, However as previously mentioned, the distinct odor of chlorine was noticed by the analytical personnel when the January 22-23 samples were first opened in the lab. Subsequent analyses confirmed its presence. The concentrations of chlorine detected in the samples substantially exceeded the tolerance limits for fishes reported by Roseboom and Richey (1977).

On March 18, 1979, the occurrence of dead fish in the lake was reported to the Illinois Department of Conservation. Personnel of that department performed an investigation (Marbut, 1979). Ice covered about 6 . percent of the lake's surface, and dissolved oxygen concentrations were about 13 mg/l. The investigation revealed that an estimated 311,7 . 7 fishes had been killed at a replacement value of \$17,489. Almost all the dead fish were gizzard shad and most of them were observed along the shoreline in the vicinity of station 5. The cause of the fish kill was not determined.

The logical suspect in that incident is the Granite City Steel Company simply because it is the only known user of chlorine that continuously discharges large quantities of water in the lake. The company uses chlorine in its wastewater treatment facilities to minimize the concentrations of ammonia-nitrogen in its treated effluent. There is no suggestion that the company has ever violated or been in non-compliance with the permits that authorize the discharge of its effluent into the lake; on the contrary, there is every evidence that it has been judicious in maintaining effluent quality equal to or better than than authorized.

What appears to be lacking is an effluent standard for residual chlorine consistent with the assimilative capacity of the lake waters and a requirement that chlorine residuals in the effluent be continuously monitored and recorded,,

SUMMARY AND CONCLUSIONS

1. *The water levels of the lake are managed in such a manner that an overall fluctuation of 24 inches occurs during summer months, often resulting in water depths of less than 2 . inches in the lake.*
2. *The waters of the lake are isothermal throughout their depth except at the "deep hole," the site of sand and gravel mining. Water temperatures average 30-34°C during July and early August. Often water temperatures will vary 4-5°C during daylight hours.*
3. *There is no significant stratification of dissolved oxygen in the lake except at the "deep hole." During daylight hours, dissolved oxygen concentrations are not likely to be less than 5 mg/l. During the summer dissolved oxygen concentrations will fluctuate 2-3 mg/l between mid-morning and mid-afternoon, on the average. Also, during the summer between 6 p.m. and 6 a.m. dissolved oxygen concentrations will decrease at rates varying from 0.3 to 0.9 mg/l/hour with the lesser rate occurring in the vicinity of Granite City Steel (GCS) effluent discharge. Dissolved oxygen concentrations may be less than 4 mg/l during nocturnal conditions.*
4. *In terms of water clarity, Horseshoe Lake is not unlike other shallow lakes in Illinois, Mean Secchi disc readings vary from 11 to 24 inches, with significant improvement in the vicinity of GCS effluents. Algal density is the regulating factor for water clarity.*
5. *The suspended solids concentration and turbidity in the lake are comparable to that of other shallow lakes in Illinois, The origin of suspended solids in the lake system is about 5 . percent algae and 5 . percent lake bottom.*
6. *Seventy algal species were recovered from the lake system, of which the dominant type is blue-green algae, especially Aphanizomenon flos-aquae. Algal densities ranged as high as 213,000 counts per milliliter. The nature and magnitude of algal populations in the lake are singular characteristics that set it apart from most, if not all, impoundments used extensively for recreation purposes in Illinois.*
7. *The alkalinity and pH of the lake waters are governed by algal densities during summer months. In the absence of algae the alkalinity of the water would probably be 12 . mg/l with a pH range of 7.5 to 8.2. During the study, alkalinity was frequently below 6 . mg/l with pH often exceeding 9.5. Waters in the vicinity of GCS effluent were not significantly influenced by algae.*

8. *Ammonia-nitrogen concentrations average 0.42- 0.57 in the lake waters.*
Though the concentrations observed are not in violation of existing standards they generally exceed the toxicity limits for the temperature and pH characteristics of the water.
9. *Phosphorus concentrations in the lake waters are comparable to those observed in other eutrophic lakes in Illinois.* Mean values for total and dissolved phosphorus range from 0.07 to 0.24 mg/l and 0.02 to 0.03 mg/l, respectively. The lower values are in the vicinity of GCS effluent. In that area 72 to 77 percent of the total phosphorus is in particulate form compared to 87-92 percent in other areas of the lake. Presumably the particulate material is algae and suspended bottom muds.
10. *The mineral quality of the lake waters is high, with mean concentrations of total dissolved solids ranging from 532 to 711 mg/l.* with the exception of strip mine lakes, the waters of Horseshoe Lake are the most highly mineralized surface water the Water Survey has investigated. Mineral quality in the lake is governed by GCS effluent. Although the maximum permissible concentration of 1000 mg/l total dissolved solids is not exceeded, the concentrations of potassium (28-70 mg/l) may pose adverse effects on some current or future aquatic inhabitants, namely mussels.
11. *Those heavy metals commonly occurring in Illinois waters (manganese, iron, copper, lead, zinc) generally do not exceed water quality standards in the lake.* There were several excursion events attributable to the resuspension of bottom muds. However cadmium concentrations were excessive during one sampling period (July), suggesting that a closer examination might be worthwhile.
12. *The bottom sediments of the lake are basically unconsolidated and easily resuspended when disturbed.* In terms of their demand for oxygen they can be classified as moderately polluted to polluted. Nevertheless their sediment oxygen demand is comparable to that of other Illinois lakes with physical features similar to that of Horseshoe Lake. A mathematical model, developed as part of the study, indicates that the dissolved oxygen resources of the lake's water can be totally depleted in less than a week if the lake waters are completely sealed from the atmosphere by ice and snow.
13. *The benthic macroinvertebrates in the bottom muds are dominated by midge fly larvae, phantom midge fly larvae, and aquatic worms.,* These organisms are representative of benthic organisms found in most mud-bottomed lakes in Illinois. They are all tolerant of organic enrichment. The mean number of organisms per square meter is 906.
14. *Zooplankton populations consist mainly of rotifers, small cladocerans, and copepods.* On an average the concentration is 1920 individuals per liter with the most productive period being the month of July. Except for *Diatomus pallidus* (copepod) there is not a viable zooplankton population in the lake after mid-September. It is probable that the major factors limiting zooplankton number and diversity are blue-green algae and selective predation by the abundant planktivorous fish.

15. *The aquatic vegetation in the lake is dominated by moist soil plants with little emergent vegetation and practically no submerged plants.* The lack of submerged plants is probably due to flocculent bottom muds, turbidity, wave action, and water level fluctuation.

The water quality of Horseshoe Lake is governed by three major agents: shallow water depth, algal productivity, and effluent from Granite City Steel. Modifications or implementation of control measures applied solely to these three factors can lead to the enhancement of water quality in the lake.

The shallowness of the lake waters, compounded by the current management of water levels, produces several adverse effects. The lake waters are very sensitive to air temperature, and the water temperatures fluctuate during daylight hours. The flocculent bottoms are resuspended by wind-generated waves, contributing to turbidity and discouraging the growth of submerged vegetation. Also, the effects of the oxygen demanding bottom sediments are more pronounced on the overlying water columns than would be the case in deeper waters.

Algal densities of bloom proportion existing on most of the water surface of the lake from mid-July to mid-October have a profound effect on the water quality. These organisms stimulate excessive daily fluctuations in dissolved oxygen concentrations and pH, contribute to suspended solids, minimize water clarity, lower the alkalinity of the water, and in general degrade the aesthetic quality of the lake system.

The effluent from the facilities of Granite City Steel has certain beneficial influences on the quality of the lake water. In the vicinity of the discharge the clarity of the water is improved, the influence of algae in terms of pH, alkalinity, and suspended solids is considerably negated, and phosphorus concentrations are reduced by dilution,, On the other hand, because of the effluents, ammonia-nitrogen concentrations are in excess of toxic limits for game fish, the possibility of chlorine doses in excess of tolerant limits is a threat, and the contribution of high potassium levels remains to be resolved.

The enhancement of water quality cannot be justified on the basis of the lake's uses in flood water retention, assimilation of waste effluent, commercial sand and gravel operation, or waterfowl hunting. Improved water quality will not augment these current uses. Only if improvement is desired in the recreational activities encompassing fishing, wildlife observations, and general aesthetics can water quality enhancement be a major consideration. On the assumption that these are considerations the following suggestions are offered:

1. Water level control as now practiced is good for waterfowl management but not for fish propagation. Can not a scheme be developed to permit that management of water level desired for waterfowl without affecting other areas of the lake? Can pumps or other drainage systems be devised for water level control in limited but ideal sectors of the lake?
2. The deepening of certain areas of the lake, not in excess of a maximum water depth of 8 feet, would be desirable. A logical area would

be that north of Walker's Island causeway in the vicinity of stations 6 and 7,

- 3, The control of algae can be achieved by chemical control using a combination of citric acid and copper sulfate applied over the entire lake surface at least 4 times per year, preferably by helicopter,
- 4, The water pollution control agencies should be encouraged to reexamine the effluent and water quality standards now applicable to Horseshoe Lake, and a plea should be made to those agencies that Horseshoe Lake is a special case with particular regard to ammonia-nitrogen, chlorine residuals, and potassium levels,
5. Some consideration should be given to minimizing the extent of ice and snow cover on the lake.

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Appendix A-1. Weather, Water Temperature, Dissolved Oxygen, and Depth, Horseshoe Lake

May 24-25

| | Station | | | | | | | |
|------------|---------|---------|---------|---------|---------|---------|---------|--------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Cloudy | Pt cldy | Pt cldy | Pt cldy | Pt cldy | Pt cldy | Pt cldy | Cloudy |
| Air temp | 31.0 | 26.6 | 26.6 | 26.6 | 24.0 | 24.0 | 24.0 | 31.0 |
| T at 0 ft | 28.0 | 27.9 | 27.5 | 26.1 | 27.2 | 28.8 | 30.0 | 29.5 |
| 1 | 27.8 | 27.0 | 26.9 | 25.0 | 27.0 | 28.8 | 30.0 | 29.5 |
| 2 | | 26.0 | 26.5 | | 27.0 | | | 29.5 |
| 3 | | 25.2 | | | | | | |
| DO at 0 ft | 8.6 | 6.8 | 6.9 | 6.2 | 11.8 | 13.2 | 15+ | 10.8 |
| 1 | 8.4 | 6.7 | 6.7 | 6.1 | 11.7 | 13.2 | 15+ | 10.8 |
| 2 | | 6.6 | 6.4 | | 11.6 | | | 10.8 |
| 3 | | 4.9 | | | | | | |
| Depth | 17 | 38 | 33 | 16 | 28 | 21 | 20 | 29 |

June 7-8

| | Station | | | | | | | |
|------------|---------|--------|--------|--------|--------|--------|--------|--------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy |
| Air temp | 27.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 27.0 |
| T at 0 ft | 26.5 | 21.8 | 23.8 | 22.0 | 20.9 | 20.2 | 20.3 | 27.2 |
| 1 | 26.1 | 22.0 | 23.8 | 21.9 | 21.0 | 20.6 | 20.3 | 27.2 |
| 2 | | 22.0 | 23.8 | | 21.0 | | | |
| 3 | | 22.0 | | | | | | |
| DO at 0 ft | 9.2 | 5.8 | 5.8 | 5.6 | 7.2 | 7.8 | 6.5 | 6.1 |
| 1 | 8.3 | 5.8 | 5.7 | 5.5 | 7.0 | 7.7 | 6.2 | 6.1 |
| 2 | | 5.8 | 5.6 | | 7.0 | | | |
| 3 | | 5.6 | | | | | | |
| Depth | 18 | 38 | 29 | 17 | 26 | 22 | 14 | 23 |

June 21-22

| | Station | | | | | | | |
|------------|---------|-------|---------|--------|-------|-------|-------|-------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Clear | Clear | Pt cldy | Cloudy | Clear | Clear | Clear | Clear |
| Air temp | 28.0 | 25.5 | 24.5 | 22.5 | 27.5 | 26.5 | 27.0 | 28.0 |
| T at 0 ft | 29.0 | 24.5 | 24.5 | 22.8 | 27.5 | 27.0 | 27.0 | 30.9 |
| 1 | 29.0 | 24.2 | 24.5 | 22.8 | 27.0 | 26.8 | 27.0 | 30.9 |
| 2 | | 24.2 | 24.5 | | | | | |
| 3 | | | | | | | | |
| DO at 0 ft | 15.7 | 7.9 | 6.8 | 7.3 | 11.2 | 12.4 | 10.4 | 10.2 |
| 1 | 15.7 | 7.9 | 6.8 | 7.1 | 10.9 | 12.2 | 10.2 | 10.2 |
| 2 | | 7.9 | 6.7 | | | | | |
| 3 | | | | | | | | |
| Depth | 16 | 30 | 27 | 14 | 17 | 17 | 13 | 18 |

Note: Temperature in degrees Celsius; dissolved oxygen in mg/l; depth in inches

Appendix A-1. Continued

July 5-6

| | Station | | | | | | | |
|------------|---------|-------|-------|-------|-------|-------|-------|------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Hazy | Clear | Clear | Clear | Clear | Clear | Clear | Hazy |
| Air temp | 32.0 | 30.0 | 30.0 | 28.5 | 33.0 | 34.5 | 32.5 | 32.0 |
| T at 0 ft | 33.2 | 29.9 | 32.0 | 27.5 | 31.5 | 32.0 | 31.0 | 34.9 |
| 1 | 33.0 | 29.3 | 31.9 | 27.5 | 31.0 | 31.3 | 30.5 | 34.8 |
| 2 | | 29.0 | 31.9 | | | | | |
| 3 | | | | | | | | |
| DO at 0 ft | 16.2 | 7.2 | 6.2 | 7.3 | 13.7 | 11.2 | 10.6 | 9.3 |
| 1 | 16.2 | 7.3 | 6.2 | 7.1 | 12.9 | 10.3 | 9.8 | 9.3 |
| 2 | | 7.3 | 6.1 | | | | | |
| 3 | | | | | | | | |
| Depth | 13 | 30 | 26 | 17 | 22 | 16 | 13 | 19 |

July 18-19

| | Station | | | | | | | |
|------------|---------|--------|--------|--------|------|---------|--------|------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Hazy | Cloudy | Cloudy | Cloudy | Hazy | Pt cldy | Cloudy | Hazy |
| Air temp | 33.0 | 27.1 | 27.2 | 27.2 | 28.5 | 27.8 | 27.0 | 34.0 |
| T at 0 ft | 34.0 | 29.0 | 31.0 | 28.5 | 30.2 | 31.0 | 30.1 | 34.0 |
| 1 | | 29.0 | 31.0 | 28.5 | 30.2 | 31.0 | 30.1 | 34.0 |
| 2 | | 29.0 | 31.0 | | | | | |
| 3 | | | | | | | | |
| DO at 0 ft | 14.1 | 8.1 | 7.2 | 7.5 | 11.2 | 10.8 | 10.6 | 10.2 |
| 1 | | 8.1 | 7.2 | 7.6 | 11.2 | 10.8 | 10.6 | 10.2 |
| 2 | | 8.1 | 7.1 | | | | | |
| 3 | | | | | | | | |
| Depth | 10 | 32 | 29 | 13 | 22 | 20 | 13 | 17 |

August 2-3

| | Station | | | | | | | |
|------------|---------|---------|---------|---------|---------|---------|---------|---------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Pt cldy | Pt cldy | Pt cldy | Pt cldy | Pt cldy | Pt cldy | Pt cldy | Pt cldy |
| Air temp | 31.0 | 30.0 | 30.0 | 29.0 | 29.0 | 29.0 | 29.0 | 30.5 |
| T at 0 ft | 31.0 | 28.5 | 30.0 | 29.5 | 29.5 | 30.2 | 30.0 | 31.0 |
| 1 | | 28.5 | 29.9 | | 29.5 | 30.2 | | 31.0 |
| 2 | | 28.2 | 29.7 | | | | | |
| 3 | | | | | | | | |
| DO at 0 ft | 12.5 | 8.8 | 5.5 | 10.8 | 11.9 | 12.2 | 11.7 | 9.3 |
| 1 | | 8.8 | 5.5 | | 11.9 | 12.4 | | 9.1 |
| 2 | | 8.3 | 5.5 | | | | | |
| 3 | | | | | | | | |
| Depth | 9 | 33 | 27 | 10 | 19 | 16 | 11 | 17 |

Appendix A-1. Continued

August 15-16

| | Station | | | | | | | |
|------------|---------|-------|-------|-------|-------|-------|-------|--------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Pt cldy | Clear | Clear | Clear | Clear | Clear | Clear | Cloudy |
| Air temp | 33.4 | 28.5 | 28.5 | 28.5 | 30.5 | 31.0 | 30.5 | 31.6 |
| T at 0 ft | 31.2 | 27.9 | 28.5 | 27.7 | 29.8 | 29.9 | 30.3 | 29.5 |
| 1 | | 27.5 | 28.3 | | 29.5 | 29.3 | | 29.2 |
| 2 | | 27.5 | 28.1 | | | | | |
| 3 | | | | | | | | |
| DO at 0 ft | 13.5 | 8.6 | 6.9 | 9.1 | 13.1 | 14.2 | 13.2 | 11.3 |
| 1 | | 8.6 | 6.9 | | 13.2 | 14.5 | | 11.0 |
| 2 | | 8.5 | 6.8 | | | | | |
| 3 | | | | | | | | |
| Depth | 5 | 31 | 27 | 10 | 19 | 18 | 11 | 21 |

August 30-31

| | Station | | | | | | | |
|------------|---------|-------|-------|-------|-------|-------|-------|---------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Pt cldy | Clear | Clear | Clear | Clear | Clear | Clear | Pt cldy |
| Air temp | 26.8 | 27.3 | 25.8 | 26.8 | 28.1 | 27.3 | 27.8 | 26.5 |
| T at 0 ft | 28.4 | 24.8 | 26.3 | 24.4 | 25.6 | 26.1 | 26.3 | 25.3 |
| 1 | | 24.6 | 26.2 | 24.3 | 25.3 | 26.0 | 26.3 | 25.2 |
| 2 | | 24.4 | 26.0 | | 25.0 | | | 25.2 |
| 3 | | 22.9 | | | | | | |
| DO at 0 ft | 14.5 | 11.4 | 8.8 | 9.2 | 12.4 | 14.2 | 13.2 | 5.5 |
| 1 | | 11.1 | 8.8 | 9.1 | 12.2 | 14.2 | 13.1 | 5.4 |
| 2 | | 10.6 | 8.8 | | 11.2 | | | 5.3 |
| 3 | | 5.6 | | | | | | |
| Depth | 2 | 40 | 33 | 18 | 25 | 21 | 18 | 29 |

September 13-14

| | Station | | | | | | | |
|------------|---------|--------|--------|--------|-------|-------|-------|---------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Pt cldy | Cloudy | Cloudy | Cloudy | Clear | Clear | Clear | Pt cldy |
| Air temp | 30.5 | 24.1 | 25.8 | 24.5 | 28.9 | 29.1 | 28.0 | 30.2 |
| T at 0 ft | 29.6 | 25.2 | 26.7 | 25.2 | 26.5 | 26.8 | 26.2 | 27.5 |
| 1 | | 25.2 | 26.7 | 25.2 | 26.5 | 26.8 | 26.2 | 27.5 |
| 2 | | 25.2 | 26.7 | 25.2 | 26.5 | 26.4 | | 27.5 |
| 3 | | 25.2 | 26.6 | | | | | |
| DO at 0 ft | 8.0 | 8.0 | 6.8 | 7.2 | 10.8 | 11.4 | 10.6 | 5.5 |
| 1 | | 7.9 | 6.8 | 7.2 | 10.7 | 11.1 | 10.6 | 5.5 |
| 2 | | 7.9 | 6.8 | 7.2 | 10.7 | 11.0 | | 5.5 |
| 3 | | 7.9 | 6.5 | | | | | |
| Depth | 1 | 45 | 42 | 25 | 30 | 28 | 23 | 33 |

Appendix A-1. Continued

September 27-28

| | Station | | | | | | | |
|------------|---------|-------|-------|-------|-------|-------|-------|-------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Pt cldy | Clear | Clear | Clear | Clear | Clear | Clear | Clear |
| Air temp* | 24 | 21 | 18 | 18 | 21 | 21 | 21 | 24 |
| T at 0 ft | 30.1 | 20.2 | 22.0 | 20.2 | 21.2 | 21.3 | 21.2 | 22.6 |
| 1 | | 20.2 | 22.0 | 20.1 | 21.4 | 21.3 | 21.2 | 21.2 |
| 2 | | 20.2 | 22.1 | 20.1 | 20.9 | 21.1 | 21.0 | 20.8 |
| 3 | | 20.2 | 22.0 | | | | | 20.6 |
| 4 | | 20.2 | | | | | | |
| DO at 0 ft | 20+ | 10.8 | 10.0 | 9.4 | 12.2 | 13.2 | 12.9 | 3.6 |
| 1 | | 10.8 | 9.9 | 9.6 | 12.0 | 13.1 | 12.8 | 3.8 |
| 2 | | 10.8 | 10.0 | 9.6 | 9.9 | 13.0 | 12.3 | 3.3 |
| 3 | | 10.8 | 9.5 | | | | | 1.1 |
| 4 | | 10.8 | | | | | | |
| Depth | 3 | 48 | 42 | 24 | 34 | 31 | 26 | 37 |

*Estimated

October 11-12

| | Station | | | | | | | |
|------------|---------|--------|--------|--------|--------|--------|--------|---------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Pt cldy | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy | Cloudy | Pt cldy |
| Air temp | 19.5 | 21.0 | 21.0 | 19.5 | 20.9 | 21.2 | 22.1 | 19.6 |
| T at 0 ft | 21.6 | 15.7 | 19.0 | 16.0 | 17.0 | 17.0 | 17.1 | 14.4 |
| 1 | | 15.7 | 19.0 | 15.9 | 16.8 | 16.8 | 17.0 | 14.4 |
| 2 | | 15.6 | 19.0 | 15.9 | 16.6 | 16.5 | 17.0 | 14.0 |
| 3 | | 15.6 | 19.1 | | | | | 13.8 |
| DO at 0 ft | 20+ | 7.1 | 6.4 | 6.3 | 8.9 | 8.9 | 9.1 | 2.7 |
| 1 | | 7.1 | 6.4 | 6.3 | 8.9 | 8.9 | 9.1 | 2.7 |
| 2 | | 7.1 | 6.4 | 5.8 | 8.9 | 8.9 | 9.1 | 2.1 |
| 3 | | 7.1 | 6.4 | | | | | 1.7 |
| Depth | 4 | 47 | 39 | 26 | 35 | 33 | 27 | 37 |

October 25-26

| | Station | | | | | | | |
|------------|---------|-------|-------|-------|-------|-------|-------|--------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Cloudy | Clear | Clear | Clear | Clear | Clear | Clear | Cloudy |
| Air temp* | 16 | 15 | 15 | 15 | 15 | 15 | 15 | 16 |
| T at 0 ft | 16.2 | 13.8 | 15.6 | 14.1 | 13.7 | 13.8 | 13.8 | 13.0 |
| 1 | | 13.8 | 15.7 | 14.1 | 13.8 | 13.8 | 13.9 | 13.0 |
| 2 | | 13.8 | 15.8 | 14.1 | 13.8 | 13.8 | 13.9 | 13.0 |
| 3 | | 13.8 | 15.8 | | | | | 12.9 |
| DO at 0 ft | 10.4 | 8.8 | 7.7 | 5.4 | 10.2 | 10.2 | 9.8 | 5.8 |
| 1 | | 8.8 | 7.6 | 5.4 | 10.2 | 10.2 | 9.8 | 5.8 |
| 2 | | 8.8 | 7.6 | 5.3 | 10.3 | 10.2 | 9.8 | 5.8 |
| 3 | | 8.8 | 7.6 | | | | | 5.5 |
| Depth | 6 | 47 | 42 | 25 | 35 | 31 | 26 | 37 |

*Estimated

Appendix A-1. Continued

November 15-16

| | Station | | | | | | | |
|------------|---------|---------|---------|---------|--------|--------|--------|--------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Cloudy | Lt rain | Lt rain | Lt rain | Cloudy | Cloudy | Cloudy | Cloudy |
| Air temp | 4.0 | 6.8 | 6.8 | 7.0 | 7.2 | 7.2 | 6.8 | 4.0 |
| T at 0 ft | 6.5 | 8.0 | 9.0 | 8.0 | 8.0 | 7.9 | 7.1 | 7.9 |
| 1 | 6.5 | 8.0 | 9.0 | 8.0 | 8.0 | 7.9 | 7.2 | 7.9 |
| 2 | | 8.0 | 9.0 | 8.0 | 8.0 | 7.9 | 7.2 | 7.9 |
| 3 | | 8.0 | 9.0 | 8.0 | 8.0 | | | 7.8 |
| 4 | | 8.0 | 9.0 | | | | | |
| DO at 0 ft | 12.4 | 9.8 | 9.2 | 8.3 | 10.1 | 10.2 | 10.8 | 10.4 |
| 1 | 12.4 | 9.8 | 9.2 | 8.3 | 10.1 | 10.2 | 10.8 | 10.4 |
| 2 | | 9.8 | 9.2 | 8.3 | 10.1 | 10.2 | 10.8 | 10.4 |
| 3 | | 9.8 | 9.2 | 8.3 | 10.1 | | | 10.3 |
| 4 | | 9.8 | 9.2 | | | | | |
| Depth | 13 | 50 | 50 | 37 | 38 | 36 | 33 | 42 |

November 29-30

| | Station | | | | | | | |
|------------|---------|-------|-------|-------|-------|-------|-------|--------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Cloudy | Clear | Clear | Clear | Clear | Clear | Clear | Cloudy |
| Air temp | 12.2 | 9.0 | 8.5 | 8.7 | 8.7 | 8.7 | 8.7 | 12.5 |
| T at 0 ft | 4.8 | 5.5 | 8.7 | 5.8 | 5.4 | 5.3 | 5.4 | 4.0 |
| 1 | 4.8 | 5.3 | 8.7 | 5.8 | 5.4 | 5.3 | 5.3 | 4.0 |
| 2 | | 4.8 | 5.2 | 8.7 | 5.6 | 5.4 | 5.3 | 4.0 |
| 3 | | | 5.0 | 8.7 | 5.4 | 5.2 | | 4.0 |
| 4 | | | 5.0 | | | | | |
| DO at 0 ft | 13.6 | 10.8 | 10.0 | 10.8 | 11.0 | 11.2 | 11.2 | 11.2 |
| 1 | 13.6 | 10.8 | 10.0 | 10.8 | 11.0 | 11.3 | 11.2 | 11.2 |
| 2 | 13.6 | 10.8 | 10.0 | 10.8 | 11.0 | 11.4 | 11.2 | 11.2 |
| 3 | | | 11.0 | 10.1 | 11.0 | 11.2 | | 11.3 |
| 4 | | | 11.0 | | | | | |
| Depth | 24 | 53 | 48 | 29 | 40 | 38 | 33 | 42 |

December 13-14

| | Station | | | | | | | |
|------------|---------|-------|-------|-------|-------|-------|-------|-------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Pt cldy | Clear | Clear | Clear | Clear | Clear | Clear | Clear |
| Air temp | 3.8 | 6.8 | 7.5 | 5.0 | 1.2 | 5.2 | 3.8 | 3.8 |
| T at 0 ft | 4.5 | 3.0 | 5.1 | 4.4 | 3.2 | 4.2 | 3.4 | 4.3 |
| 1 | 4.8 | 4.0 | 5.1 | 4.4 | 2.9 | 4.6 | 3.8 | 4.3 |
| 2 | | 4.3 | 5.1 | 4.5 | 2.9 | 4.7 | 3.9 | 4.3 |
| 3 | | 4.3 | 5.1 | | 3.0 | | | 4.3 |
| 4 | | 4.3 | | | | | | |
| DO at 0 ft | 19.5 | 8.6 | 8.2 | 10.6 | 9.2 | 10.6 | 10.2 | 13.6 |
| 1 | 19.5 | 8.6 | 8.1 | 10.6 | 9.4 | 10.8 | 10.2 | 13.6 |
| 2 | | 8.5 | 8.1 | 10.8 | 9.8 | 10.9 | 10.2 | 13.6 |
| 3 | | 8.5 | 8.1 | | 9.8 | | | 13.6 |
| 4 | | 8.5 | | | | | | |
| Depth | 22 | 49 | 43 | 25 | 36 | 32 | 28 | 38 |

Appendix A-1. Concluded

January 8-9

| | Station | | | | | | | |
|------------|---------|-------|-------|-------|-------|-------|-------|-------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear |
| Air temp | -12 | -8 | -6 | -12 | -8 | -12 | -8 | -12 |
| T at 0 ft | 0.8 | 1.0 | 1.2 | 0.3 | 1.0 | 0.9 | 2.0 | 2.0 |
| 1 | 1.3 | 1.2 | 1.5 | 1.1 | 1.7 | 1.2 | 2.0 | 2.0 |
| 2 | | 2.1 | 2.1 | 2.5 | 2.5 | 1.2 | 3.0 | 2.0 |
| 3 | | 3.2 | | | | | | 2.0 |
| DO at 0 ft | 18.8 | 10.4 | 9.8 | 6.3 | 5.0 | 7.7 | 9.7 | 12.5 |
| 1 | 18.8 | 10.6 | 9.8 | 4.6 | 5.3 | 7.5 | 9.8 | 12.4 |
| 2 | | 10.6 | 9.8 | 1.9 | 6.3 | 7.4 | 7.8 | 12.4 |
| 3 | | 7.4 | | | | | | 12.4 |
| Depth | 20 | 37 | 35 | 26 | 34 | 32 | 26 | 36 |

January 22-23

| | Station | | | | | | | |
|------------|---------|------|------|--------|---------|---------|------|------|
| | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 9 |
| Weather | Pt cldy | Snow | Snow | Cloudy | Fz rain | Fz rain | Snow | Hazy |
| Air temp | 2.5 | 0.5 | 0.0 | 0.0 | 4.0 | 1.5 | 0.0 | 2.5 |
| T at 0 ft | 2.1 | 2.1 | 3.0 | 1.0 | 1.0 | 1.8 | 1.9 | 4.0 |
| 1 | 3.2 | 2.5 | 3.8 | 1.0 | 2.0 | 2.0 | 2.0 | 4.0 |
| 2 | | 4.2 | 3.8 | | 3.5 | 2.2 | 4.2 | 4.0 |
| 3 | | 4.2 | | | 3.7 | | | 4.0 |
| 4 | | 4.3 | | | | | | |
| DO at 0 ft | 6.3 | 8.9 | 12.2 | 6.8 | 5.0 | 12.3 | 8.7 | 12.2 |
| 1 | 5.4 | 8.9 | 12.3 | 6.6 | 6.2 | 12.3 | 8.6 | 12.4 |
| 2 | | 10.4 | 12.3 | | 6.9 | 12.3 | 10.4 | 12.4 |
| 3 | | 10.5 | | | 6.7 | | | 12.4 |
| 4 | | 10.6 | | | | | | |
| Depth | 22 | 48 | 35 | 22 | 37 | 32 | 26 | 36 |

Appendix A-2. Water Temperature at Station 5,
Horseshoe Lake

(Temperature in degrees Celsius)

| Depth (feet) | May 25 | June 8 | June 22 | July 6 | July 19 | Aug 3 | Aug 16 | Aug 31 |
|-----------------|-----------|-----------|------------|-----------|------------|----------|-----------|-----------|
| 0 | 29.1 | 22.5 | 25.0 | 31.5 | 30.0 | 28.5 | 28.0 | 25.9 |
| 1 | 28.0 | 22.5 | 25.0 | 30.2 | 30.0 | 28.5 | 27.5 | 26.0 |
| 2 | 26.0 | 22.7 | 25.0 | 29.9 | 30.0 | 28.2 | 27.5 | 26.0 |
| 3 | 25.3 | 22.7 | 25.0 | 29.5 | 30.0 | 28.0 | 27.3 | 25.8 |
| 4 | 24.9 | 22.7 | 25.0 | 29.1 | 29.8 | 27.0 | 27.2 | 25.0 |
| 5 | | 22.7 | 25.0 | 29.0 | 29.8 | 26.5 | 27.0 | 24.2 |
| 6 | 24.2 | 22.8 | 25.0 | 28.3 | 29.1 | 26.1 | 26.4 | 24.0 |
| 8 | 22.0 | 22.8 | 24.5 | 28.0 | 28.0 | 26.0 | 26.0 | 23.9 |
| 10 | 20.3 | 22.2 | 24.0 | 27.6 | 26.8 | 25.7 | 25.8 | 23.8 |
| 12 | 18.2 | 21.3 | 23.5 | 26.2 | 25.1 | 25.2 | 25.5 | 23.3 |
| 14 | 16.5 | 20.8 | 23.0 | 24.1 | 24.0 | 25.0 | 25.2 | 23.3 |
| 16 | 15.1 | 19.0 | 21.0 | 21.8 | 22.9 | 24.0 | 24.2 | 23.3 |
| 18 | 14.8 | 16.0 | 19.0 | 20.0 | 21.5 | 22.5 | 23.0 | 23.3 |
| 20 | 14.5 | 15.6 | 17.5 | 18.1 | 20.1 | 20.2 | 22.0 | 23.6 |
| 25 | 14.1 | 14.9 | 16.0 | 16.5 | 18.0 | 18.5 | 20.0 | 22.8 |
| 30 | 14.0 | 14.6 | 15.5 | 16.0 | 17.0 | 17.2 | 17.7 | 21.5 |
| 35 | 14.0 | 14.3 | 15.2 | 15.6 | 16.5 | 16.7 | 17.0 | 19.0 |
| 40 | 13.9 | 14.2 | 15.0 | 15.1 | 16.1 | 16.3 | 16.8 | 18.6 |
| 45 | 13.7 | | 15.0 | | 16.0 | | | |

| Depth (feet) | Sep 14 | Sep 28 | Oct 12 | Oct 26 | Nov 16 | Nov 30 | Dec 14 | Jan 9 | Jan 23 |
|-----------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|-----------|
| 0 | 25.7 | 20.7 | 16.3 | 13.4 | 9.2 | 5.3 | 3.0 | 1.5 | 1.8 |
| 1 | 25.7 | 20.7 | 16.2 | 13.4 | 9.2 | 5.3 | 3.0 | 1.5 | 2.5 |
| 2 | 25.7 | 20.7 | 16.0 | 13.4 | 9.2 | 5.2 | 3.0 | 2.0 | 2.6 |
| 3 | 25.7 | 20.7 | 15.8 | 13.4 | 9.2 | 5.2 | 2.8 | 2.0 | 2.9 |
| 4 | 25.7 | 20.7 | 15.5 | 13.4 | 9.2 | 5.2 | 2.8 | 2.0 | 3.0 |
| 5 | 25.7 | 20.8 | 15.2 | 13.4 | 9.2 | 5.1 | 2.8 | 2.1 | 3.0 |
| 6 | 25.7 | 20.8 | 14.7 | 13.4 | 9.2 | 5.1 | 2.8 | 2.1 | 3.0 |
| 8 | 25.7 | 20.7 | 14.4 | 13.4 | 9.2 | 5.1 | 2.8 | 2.1 | 3.0 |
| 10 | 25.7 | 20.6 | 14.2 | 13.4 | 9.5 | 5.1 | 2.8 | 2.1 | 3.0 |
| 12 | 25.7 | 20.4 | 14.2 | 13.3 | 9.5 | 5.1 | 2.8 | 2.1 | 3.0 |
| 14 | 25.2 | 20.2 | 14.0 | 13.2 | 9.5 | 5.1 | 2.8 | 2.2 | 3.0 |
| 16 | 25.0 | 20.2 | 14.0 | 13.1 | 9.5 | 5.1 | 2.8 | 2.2 | 3.0 |
| 18 | 25.0 | 20.2 | 14.0 | 13.1 | 9.5 | 5.0 | 2.7 | 2.2 | 3.0 |
| 20 | 24.8 | 20.1 | 14.0 | 13.0 | 9.5 | 5.0 | 2.8 | 2.2 | 3.1 |
| 25 | 23.0 | 20.0 | 14.0 | 12.9 | 9.0 | 4.9 | 2.8 | 2.3 | 3.2 |
| 30 | 21.8 | 20.0 | 14.0 | 12.7 | 9.2 | 4.9 | 2.9 | 2.3 | 3.2 |
| 35 | 20.5 | 20.0 | 14.0 | 12.3 | 9.2 | 4.9 | 3.0 | 2.3 | 3.2 |
| 40 | 19.8 | 20.0 | 14.0 | 12.1 | 9.2 | 4.8 | 3.0 | 2.3 | 3.2 |
| 45 | 19.8 | 20.0 | 14.0 | 12.1 | 9.2 | 4.8 | 3.0 | | 3.3 |
| 50 | | | | | | 5.0 | | | |

Appendix A-3. Dissolved Oxygen, Weather, and Depth at Station 5, Horseshoe Lake

| | May 25 | Jun 8 | Jun 22 | Jul 6 | Jul 19 | Aug 3 | Aug 16 | Aug 31 |
|------------|-----------|----------|-----------|----------|-----------|----------|-----------|-----------|
| Weather | Pt cldy | Cloudy | Clear | Clear | Cloudy | Pt cldy | Clear | Clear |
| Air temp | 26.6 | 15.0 | 25.2 | 31.5 | 31.0 | 29.0 | 28.5 | 27.3 |
| DO at 0 ft | 15.4 | 5.5 | 8.4 | 9.3 | 7.7 | 9.1 | 6.4 | 10.0 |
| 1 | 15.4 | 5.4 | 8.4 | 9.2 | 7.8 | 8.9 | 6.2 | 10.0 |
| 2 | 15.4 | 5.2 | 8.3 | 7.0 | 7.6 | 8.7 | 6.1 | 9.8 |
| 3 | 14.6 | 5.3 | 8.2 | 6.1 | 7.6 | 8.4 | 5.8 | 9.3 |
| 4 | 13.5 | 5.2 | 8.2 | 5.1 | 7.6 | 4.2 | 5.5 | 8.0 |
| 5 | | 5.2 | 8.2 | 6.7 | 7.6 | 2.4 | 3.9 | 5.5 |
| 6 | 8.5 | 5.2 | 8.1 | 6.3 | 6.5 | 2.1 | 2.8 | 3.9 |
| 8 | 5.5 | 5.0 | 7.2 | 5.3 | 1.0 | 2.2 | 2.8 | 2.9 |
| 10 | 4.2 | 3.4 | 6.7 | 1.0 | 0.2 | 1.0 | 2.5 | 2.8 |
| 12 | 1.9 | 2.6 | 3.2 | 1.8 | 0.2 | 0.2 | 2.1 | 3.0 |
| 14 | 0.6 | 2.5 | 0.8 | 1.2 | 0.2 | 0.2 | 1.6 | 3.0 |
| 16 | 0.5 | 0.5 | 0.2 | 0.3 | 0.2 | 0.2 | 0.3 | 3.0 |
| 18 | 0.3 | 0.4 | 0.1 | 0.3 | 0.2 | 0.2 | 0.3 | 2.9 |
| 20 | 0.2 | 0.4 | 0.1 | 0.3 | 0.2 | 0.2 | 0.3 | 2.8 |
| 25 | 0.2 | 0.4 | 0.1 | 0.3 | 0.2 | 0.2 | 0.3 | 0.1 |
| 30 | 0.2 | 0.3 | 0.1 | 0.3 | 0.2 | 0.2 | 0.3 | 0.1 |
| 35 | 0.2 | 0.3 | 0.1 | 0.3 | 0.2 | 0.2 | 0.3 | 0.1 |
| 40 | 0.2 | 0.3 | 0.1 | 0.3 | 0.2 | 0.2 | 0.3 | 0.1 |
| 45 | 0.2 | | 0.1 | | 0.2 | | 0.3 | 0.1 |
| 50 | | | | | 0.2 | | | |
| Depth | 47 | 43 | 46 | 43 | 46 | 44 | 41 | 43 |

| | Sep 14 | Sep 28 | Oct 12 | Oct 26 | Nov 16 | Nov 30 | Dec 14 | Jan 9 | Jan 23 |
|------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|-----------|
| Weather | Pt cldy | Clear | Cloudy | Clear | Cloudy | Clear | Clear | Clear | Snow |
| Air temp | 25.0 | 21 | 21.0 | 11.0 | 6.8 | 8.7 | 7.9 | -6 | 0 |
| DO at 0 ft | 5.7 | 7.9 | 8.4 | 8.1 | 8.3 | 9.9 | 9.0 | 9.8 | 12.3 |
| 1 | 5.6 | 7.8 | 8.4 | 8.1 | 8.3 | 9.9 | 9.0 | 9.8 | 11.9 |
| 2 | 5.6 | 7.8 | 8.3 | 8.1 | 8.3 | 9.9 | 9.0 | 9.7 | 11.8 |
| 3 | 5.5 | 7.9 | 7.9 | 8.0 | 8.3 | 9.9 | 9.0 | 9.7 | 11.8 |
| 4 | 5.5 | 8.4 | 7.6 | 8.1 | 8.1 | 10.0 | 9.0 | 9.7 | 11.8 |
| 5 | 5.5 | 8.5 | 6.6 | 8.1 | 8.1 | 10.0 | 9.0 | 9.7 | 11.8 |
| 6 | 5.5 | 8.5 | 6.0 | 8.1 | 8.1 | 10.0 | 9.0 | 9.7 | 11.8 |
| 8 | 5.5 | 8.4 | 5.7 | 8.1 | 8.1 | 10.0 | 9.0 | 9.7 | 11.8 |
| 10 | 5.5 | 9.0 | 5.5 | 8.1 | 8.0 | 10.0 | 9.0 | 9.6 | 11.8 |
| 12 | 5.2 | 8.6 | 5.5 | 8.0 | 8.0 | 10.0 | 9.1 | 9.6 | 11.8 |
| 14 | 2.8 | 6.6 | 5.5 | 8.0 | 8.0 | 10.0 | 9.1 | 9.6 | 11.8 |
| 16 | 2.5 | 4.8 | 5.4 | 7.7 | 8.0 | 10.0 | 9.1 | 9.6 | 11.8 |
| 18 | 1.5 | 5.0 | 5.4 | 7.5 | 8.0 | 10.1 | 9.0 | 9.6 | 11.8 |
| 20 | 0.0 | 5.8 | 5.4 | 6.8 | 8.0 | 10.1 | 9.0 | 9.6 | 11.8 |
| 25 | 0.0 | 5.9 | 5.4 | 6.5 | 8.5 | 10.2 | 8.9 | 9.5 | 11.8 |
| 30 | 0.0 | 5.8 | 5.5 | 5.6 | 8.5 | 10.0 | 8.9 | 9.5 | 11.8 |
| 35 | 0.0 | 6.0 | 5.4 | 4.2 | 8.5 | 10.0 | 8.8 | 9.4 | 11.8 |
| 40 | 0.0 | 5.7 | 5.5 | 3.0 | 8.5 | 10.0 | 8.8 | 9.4 | 11.8 |
| 45 | 0.0 | 5.4 | 4.6 | 2.6 | 8.5 | 10.0 | 8.4 | | 11.0 |
| 50 | | | | | 9.9 | | | | |
| Depth | 48 | 46 | 46 | 48 | 48 | 51 | 46 | 44 | 46 |

Note: Temperature in degrees Celsius; dissolved oxygen in mg/l; depth in feet

Appendix B-1. Water Quality Characteristics, Horseshoe Lake

| Station 1 | | | | | | | | | |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------------|--------------|--------------|
| | May 24-25 | Jun 7-8 | Jun 21-22 | Jul 5-6 | Jul 18-19 | Aug 2-3 | Aug 15-16 | Aug 30-31 | |
| Secchi (in) | 6 | 5 | 4 | 6 | 4 | 4 | 3 | 3* | |
| pH (units) | 8.65 | 8.66 | 9.43 | 9.54 | 9.69 | 9.25 | 10.15 | 10.41 | |
| Alk | 91.3 | 104.6 | 111.6 | 110.4 | 81.9 | 90.9 | 66.7 | 48.2 | |
| Turb (NTU) | 26.3 | 54.0 | 36.2 | 31.8 | 33.7 | 51.0 | 68.3 | 135.0 | |
| Ammonia-N | 0.02 | 0.02 | 0.16 | 0.00 | 0.07 | 0.01 | 0.11 | 0.24 | |
| Diss solids | 552 | 319 | 388 | 345 | 364 | 387 | 441 | 472 | |
| Susp solids | 131 | 279 | 135 | 351 | 212 | 254 | 292 | 564 | |
| T phos | 0.60 | 1.04 | 0.56 | 0.85 | 0.99 | 0.96 | 1.33 | 2.01 | |
| Diss phos | 0.08 | 0.09 | 0.15 | 0.10 | 0.15 | 0.14 | 0.13 | 0.14 | |
| * Estimated | | | | | | | | | |
| | Sep 13-14 | Sep 27-28 | Oct 11-12 | Oct 25-26 | Nov 15-16 | Nov 29-30 | Dec 13-14 | Jan 8-9 | Jan 22-23 |
| Secchi (in) | | 5* | 4 | 3 | 5 | 7 | 15 | 20+ | 22+ |
| pH (units) | 10.23 | 10.36 | 10.30 | 9.13 | 8.08 | 8.90 | 9.32 | 9.08 | 7.61 |
| Alk | 49.2 | 49.2 | 73.8 | 73.8 | 93.0 | 86.1 | 96.4 | 112.8 | 129.2 |
| Turb (NTU) | 64.6 | 21.7 | 44.3 | 47.0 | 18.7 | 12.8 | 10.2 | 7.2 | 8.9 |
| Ammonia-N | 0.48 | 0.02 | 0.04 | 0.12 | 0.24 | 0.35 | 0.25 | 0.17 | 0.68 |
| Diss solids | 648 | 672 | 721 | 705 | 620 | 587 | 540 | 649 | 638 |
| Susp solids | 292 | 88 | 228 | 248 | 87 | 48 | 17 | 22 | 6 |
| T phos | 3.17 | 1.14 | 1.59 | 0.99 | 0.35 | 0.20 | 0.12 | 0.11 | 0.10 |
| Diss phos | 1.93 | 0.11 | 0.05 | 0.09 | 0.02 | 0.03 | 0.01 | 0.02 | 0.05 |
| * Estimated | | | | | | | | | |
| | | | | | | | Residual chlorine | 0 | |
| Station 2 | | | | | | | | | |
| | May 24-25 | Jun 7-8 | Jun 21-22 | Jul 5-6 | Jul 18-19 | Aug 2-3 | Aug 15-16 | Aug 30-31 | |
| Secchi (in) | 14 | 7 | 14 | 18 | 10 | 8 | 8 | 8 | |
| pH (units) | 8.21 | 8.15 | 8.58 | 9.11 | 9.91 | 9.46 | 9.51 | 9.81 | |
| Alk | 92.5 | 124.2 | 109.9 | 59.8 | 39.3 | 50.6 | 64.4 | 49.2 | |
| Turb (NTU) | 13.0 | 17.0 | 4.2 | 5.9 | 10.9 | 13.3 | 18.9 | 13.5 | |
| Ammonia-N | 0.38 | 2.19 | 0.79 | 0.10 | 0.16 | 0.09 | 0.03 | 0.07 | |
| Diss solids | 723 | 587 | 620 | 572 | 556 | 565 | 641 | 700 | |
| Susp solids | 23 | 59 | 30 | 27 | 54 | 192 | 68 | 29 | |
| T phos | 0.11 | 0.20 | 0.13 | 0.10 | 0.16 | 0.25 | 0.18 | 0.17 | |
| Diss phos | Tr | 0.02 | 0.01 | 0.02 | 0.01 | 0.05 | 0.01 | 0.02 | |
| | Sep 13-14 | Sep 27-28 | Oct 11-12 | Oct 25-26 | Nov 15-16 | Nov 29-30 | Dec 13-14 | Jan 8-9 | Jan 22-23 |
| Secchi (in) | 5 | 7 | 12 | 22 | 36 | 53 | 49 | 37+ | 48+ |
| pH (units) | 9.57 | 9.39 | 8.15 | 8.31 | 8.00 | 7.29 | 8.30 | 7.87 | 7.60 |
| Alk | 45.1 | 53.3 | 82.0 | 105.6 | 117 | 129.2 | 137.4 | 153.8 | 166.1 |
| Turb (NTU) | 33.3 | 28.0 | 7.7 | 6.0 | 1.2 | 2.4 | 3.0 | 6.2 | 4.9 |
| Ammonia-N | 0.14 | 0.04 | 0.35 | 0.83 | 1.63 | 1.25 | 1.00 | 0.93 | 1.46 |
| Diss solids | 648 | 664 | 687 | 724 | 687 | 691 | 668 | 778 | 739 |
| Susp solids | 66 | 62 | 15 | 21 | 5 | 4 | 3 | 19 | 3 |
| T phos | 0.18 | 0.15 | 0.08 | 0.08 | 0.04 | 0.06 | 0.02 | 0.03 | 0.02 |
| Diss phos | 0.10 | 0.02 | 0.06 | 0.02 | 0.01 | 0.04 | 0.02 | 0.01 | 0.01 |
| | | | | | | | Residual chlorine | 0 | |

Note: Concentrations in mg/l unless otherwise indicated

Residual chlorine 0

Appendix B-1. Continued

| Station 3 | | | | | | | | | |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|------------------------|
| | May 24-25 | Jun 7-8 | Jun 21-22 | Jul 5-6 | Jul 18-19 | Aug 2-3 | Aug 15-16 | Aug 30-31 | |
| Secchi (in) | 24 | 11 | 11 | 20 | 16 | 17 | 15 | 17 | |
| pH (units) | 7.69 | 7.78 | 8.24 | 8.05 | 8.28 | 7.95 | 8.10 | 8.20 | |
| Alk | 137.3 | 133.4 | 131.1 | 128.8 | 109.9 | 131.1 | 89.7 | 147.2 | |
| Turb (NTU) | 5.2 | 10.4 | 7.4 | 7.4 | 6.0 | 8.5 | 21.0 | 2.2 | |
| Ammonia-N | 0.33 | 0.84 | 0.62 | 0.82 | 0.34 | 0.39 | 1.58 | 0.16 | |
| Diss solids | 714 | 778 | 760 | 718 | 615 | 757 | 813 | 701 | |
| Susp solids | 5 | 60 | 37 | 26 | 24 | 200 | 48 | 9 | |
| T phos | 0.11 | 0.12 | 0.13 | 0.08 | 0.10 | 0.07 | 0.08 | 0.08 | |
| Diss phos | Tr | 0.02 | 0.01 | 0.05 | 0.01 | 0.03 | Tr | 0.03 | |
| | Sep 13-14 | Sep 27-28 | Oct 11-12 | Oct 25-26 | Nov 15-16 | Nov 29-30 | Dec 13-14 | Jan 8-9 | Jan 22-23 |
| Secchi (in) | 9 | 14 | 27 | 31 | 36 | 48+ | 43+ | 35+ | 35+ |
| pH (units) | 8.05 | 8.50 | 7.32 | 7.52 | 7.66 | 7.29 | 7.40 | 6.96 | 7.10 |
| Alk | 118.9 | 135.3 | 114.8 | 125.1 | 121.0 | 129.2 | 134.3 | 152.0 | 132.2 |
| Turb (NTU) | 19.0 | 3.5 | 4.3 | 4.0 | 1.5 | 2.5 | 5.5 | 4.5 | 3.5 |
| Ammonia-N | 0.22 | 0.66 | 0.35 | 0.68 | 0.81 | 0.61 | 0.68 | 0.89 | 0.83 |
| Diss solids | 587 | 733 | 687 | 653 | 703 | 758 | 704 | 685 | 724 |
| Susp solids | 31 | 25 | 5 | 11 | 2 | 4 | 4 | 7 | 1 |
| T phos | 2.40* | 0.14 | 0.05 | 0.06 | 0.03 | 0.03 | 0.02 | 0.03 | 0.02 |
| Diss phos | 2.39* | 0.04 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.03 | 0.02 |
| | | | | | | | | | Residual chlorine 0.35 |

* Questionable, not included in computations

| Station 4 | | | | | | | | | |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|------------------------|
| | May 24-25 | Jun 7-8 | Jun 21-22 | Jul 5-6 | Jul 18-19 | Aug 2-3 | Aug 15-16 | Aug 30-31 | |
| Secchi (in) | 9 | 9 | 8 | 6 | 8 | 9 | 6 | 7 | |
| pH (units) | 8.36 | 8.12 | 8.51 | 9.21 | 8.29 | 8.83 | 8.71 | 8.89 | |
| Alk | 96.6 | 131.1 | 85.1 | 49.5 | 89.7 | 99.1 | 73.6 | 82.0 | |
| Turb (NTU) | 10.5 | 16.4 | 21.8 | 29.8 | 14.1 | 15.4 | 39.2 | 22.5 | |
| Ammonia-N | 0.25 | 1.53 | 0.19 | 0.15 | 0.37 | 0.11 | 0.21 | 0.21 | |
| Diss solids | 343 | 550 | 522 | 495 | 673 | 529 | 622 | 551 | |
| Susp solids | 36 | 65 | 155 | 162 | 72 | 60 | 202 | 96 | |
| T phos | 0.25 | 0.19 | 0.37 | 0.40 | 0.21 | 0.21 | 0.42 | 0.44 | |
| Diss phos | Tr | 0.02 | 0.02 | 0.02 | 0.03 | 0.05 | 0.02 | 0.06 | |
| | Sep 13-14 | Sep 27-28 | Oct 11-12 | Oct 25-26 | Nov 15-16 | Nov 29-30 | Dec 13-14 | Jan 8-9 | Jan 22-23 |
| Secchi (in) | 8 | 8 | 12 | 19 | 14 | 24 | 25 | 8 | |
| pH (units) | 8.87 | 8.90 | 7.75 | 7.58 | 7.80 | 8.14 | 8.10 | 7.15 | 7.31 |
| Alk | 172.2 | 96.4 | 171.8 | 174.3 | 98.0 | 120.5 | 131.2 | 162.0 | 98.4 |
| Turb (NTU) | 33.9 | 14.0 | 10.2 | 10.0 | 6.3 | 4.3 | 3.9 | 7.1 | 12.2 |
| Ammonia-N | 0.20 | 0.52 | 0.34 | 0.47 | .58 | .69 | 1.07 | 1.07 | |
| Diss solids | 692 | 652 | 653 | 543 | 462 | 629 | 530 | 606 | 752 |
| Susp solids | 58 | 63 | 28 | 20 | 25 | 9 | 8 | 16 | 24 |
| T phos | 0.32 | 0.19 | 0.10 | 0.11 | 0.18 | 0.08 | 0.07 | 0.14 | 0.18 |
| Diss phos | 0.06 | 0.02 | 0.02 | 0.03 | 0.02 | 0.03 | 0.02 | 0.02 | 0.04 |
| | | | | | | | | | Residual chlorine 0.26 |

Appendix B-1. Continued

Station 5 (top)

| | May 24-25 | Jun 7-8 | Jun 21-22 | Jul 5-6 | Jul 18-19 | Aug 2-3 | Aug 15-16 | Aug 30-31 |
|-------------|--------------|------------|--------------|------------|--------------|------------|--------------|--------------|
| Secchi (in) | 9 | 10 | 13 | 8 | 8 | 7 | 9 | 10 |
| pH (units) | 8.89 | 8.16 | 8.50 | 9.00 | 9.52 | 8.89 | 8.40 | 8.59 |
| Alk | 80.5 | 131.1 | 89.9 | 60.5 | 46.5 | 87.4 | 80.5 | 98.4 |
| Turb (NTU) | 10.5 | 15.3 | 6.3 | 15.6 | 11.0 | 15.4 | 17.4 | 5.0 |
| Ammonia-N | 0.12 | 1.54 | 0.24 | 0.12 | 0.09 | 0.19 | 0.28 | 0.53 |
| Diss solids | 494 | 509 | 595 | 516 | 539 | 588 | 660 | 629 |
| Susp solids | 28 | 41 | 32 | 47 | 40 | 35 | 54 | 20 |
| T phos | 0.09 | 0.20 | 0.14 | 0.20 | 0.23 | 0.07 | 0.16 | 0.11 |
| Diss phos | 0.06 | 0.01 | 0.02 | 0.06 | 0.01 | 0.05 | 0.01 | 0.04 |

| | Sep 13-14 | Sep 27-28 | Oct 11-12 | Oct 25-26 | Nov 15-16 | Nov 29-30 | Dec 13-14 | Jan 8-9 | Jan 22-23 |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|------------|--------------|
| Secchi (in) | 8 | 9 | 11 | 13 | 22 | 22 | 42 | 31 | 42 |
| pH (units) | 8.76 | 8.68 | 8.50 | 8.23 | 7.93 | 8.10 | 7.63 | 7.59 | 7.04 |
| Alk | 81.0 | 82.6 | 94.9 | 108.7 | 114.0 | 118.5 | 132.2 | 155.8 | 148.6 |
| Turb (NTU) | 21.9 | 18.2 | 14.3 | 10.0 | 3.9 | 3.9 | 4.5 | 4.2 | 8.9 |
| Ammonia-N | 0.27 | 0.30 | 0.31 | 0.72 | 0.97 | 0.99 | 0.84 | 0.79 | 1.34 |
| Diss solids | 683 | 599 | 663 | 633 | 641 | 618 | 611 | 668 | 681 |
| Susp solids | 38 | 34 | 20 | 32 | 13 | 13 | 5 | 10 | 1 |
| T phos | 0.24 | 0.13 | 0.12 | 0.11 | 0.10 | 0.09 | 0.06 | 0.04 | 0.04 |
| Diss phos | 0.06 | 0.02 | 0.01 | 0.03 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |

Residual chlorine 1.5

Station 5 (bottom)

| | May 24-25 | Jun 7-8 | Jun 21-22 | Jul 5-6 | Jul 18-19 | Aug 2-3 | Aug 15-16 | Aug 30-31 |
|-------------|--------------|------------|--------------|------------|--------------|------------|--------------|--------------|
| pH (units) | 7.60 | 7.50 | 7.57 | 7.60 | 7.51 | 7.48 | 7.52 | 7.40 |
| Alk (mg/l) | 126.5 | 152.0 | 154.1 | 174.8 | 197.8 | 189.8 | 215.1 | 233.7 |
| Turb (NTU) | 13.0 | 16.0 | 8.0 | 11.2 | 14.1 | 15.4 | 16.7 | 15.7 |
| Ammonia-N | 1.03 | 2.16 | 1.33 | 1.50 | 2.52 | 2.26 | 3.25 | 3.57 |
| Diss solids | 466 | 460 | 508 | 461 | 481 | 491 | 539 | 496 |
| Susp solids | 43 | 40 | 30 | 27 | 24 | 30 | 50 | 38 |
| T phos | 0.20 | 0.32 | 0.19 | 0.15 | 0.26 | 0.21 | 0.22 | 0.33 |
| Diss phos | 0.01 | 0.02 | 0.02 | 0.01 | 0.04 | 0.03 | 0.01 | 0.02 |

| | Sep 13-14 | Sep 27-28 | Oct 11-12 | Oct 25-26 | Nov 15-16 | Nov 29-30 | Dec 13-14 | Jan 8-9 | Jan 22-23 |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|------------|--------------|
| pH (units) | 7.50 | 8.39 | 7.98 | 7.63 | 7.96 | 8.06 | 7.92 | 7.43 | 7.03 |
| Alk (mg/l) | 244.0 | 86.1 | 99.2 | 108.7 | 119.0 | 122.0 | 131.2 | 166.1 | 155.8 |
| Turb (NTU) | 29.3 | 20.3 | 10.1 | 14 | 24.8 | 4.4 | 7.0 | 5.3 | 5.3 |
| Ammonia-N | 3.52 | 0.39 | 0.47 | 1.19 | 1.02 | 0.88 | 0.85 | 0.74 | 1.27 |
| Diss solids | 527 | 620 | 650 | 640 | 637 | 628 | 635 | 710 | 745 |
| Susp solids | 45 | 46 | 23 | 30 | 130 | 16 | 6 | 8 | 1 |
| T phos | 0.52 | 0.18 | 0.12 | 0.13 | 0.19 | 0.09 | 0.05 | 0.04 | 0.03 |
| Diss phos | 0.07 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 |

Residual chlorine 1.5

Appendix B-1. Continued

Station 6

| | May 24-25 | Jun 7-8 | Jun 21-22 | Jul 5-6 | Jul 18-19 | Aug 2-3 | Aug 15-16 | Aug 30-31 |
|-------------|--------------|------------|--------------|------------|--------------|------------|--------------|--------------|
| Secchi (in) | 8 | 6 | 6 | 5 | 4 | 6 | 6 | 5 |
| pH (units) | 8.58 | 8.39 | 9.00 | 9.65 | 10.14 | 9.36 | 9.14 | 9.52 |
| Alk | 111.6 | 133.9 | 78.2 | 71.3 | 48.3 | 74.8 | 96.6 | 61.1 |
| Turb (NTU) | 13.2 | 22.4 | 26.6 | 31.8 | 28.9 | 22.9 | 39.2 | 15.7 |
| Ammonia-N | 0.07 | 0.85 | 0.19 | 0.20 | 0.25 | 0.05 | 0.10 | 0.15 |
| Diss solids | 359 | 418 | 585 | 417 | 480 | 458 | 602 | 575 |
| Susp solids | 49 | 79 | 89 | 102 | 136 | 93 | 124 | 44 |
| T phos | 0.35 | 0.37 | 0.33 | 0.37 | 0.42 | 0.30 | 0.36 | 0.24 |
| Diss phos | 0.02 | 0.02 | 0.03 | 0.01 | 0.02 | 0.07 | 0.01 | 0.07 |

| | Sep 13-14 | Sep 27-28 | Oct 11-12 | Oct 25-26 | Nov 15-16 | Nov 29-30 | Dec 13-14 | Jan 8-9 | Jan 22-23 |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|------------|--------------|
| Secchi (in) | 5 | 7 | 10 | 11 | 18 | 25 | 27 | 34+ | 23 |
| pH (units) | 9.80 | 9.36 | 8.62 | 8.65 | 8.17 | 8.18 | 7.32 | 6.65 | 7.30 |
| Alk | 55.4 | 61.5 | 96.4 | 92.3 | 108.0 | 123.4 | 127.1 | 141.5 | 194.8 |
| Turb (NTU) | 33.9 | 25.9 | 15.4 | 14.0 | 4.9 | 3.0 | 3.1 | 5.3 | 5.2 |
| Ammonia-N | 0.21 | 0.02 | 0.26 | 0.64 | 0.64 | 0.78 | 0.49 | 0.19 | 0.66 |
| Diss solids | 582 | 622 | 699 | 626 | 600 | 615 | 498 | 563 | 547 |
| Susp solids | 84 | 29 | 25 | 35 | 15 | 12 | 7 | 12 | 10 |
| T phos | 0.30 | 0.18 | 0.13 | 0.17 | 0.11 | 0.12 | 0.11 | 0.18 | 0.12 |
| Diss phos | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | 0.02 |

Residual chlorine 0

Station 7

| | May 24-25 | Jun 7-8 | Jun 21-22 | Jul 5-6 | Jul 18-19 | Aug 2-3 | Aug 15-16 | Aug 30-31 |
|-------------|--------------|------------|--------------|------------|--------------|------------|--------------|--------------|
| Secchi (in) | 7 | 5 | 5 | 5 | 5 | 5 | 6 | 6 |
| pH (units) | 8.87 | 8.46 | 9.50 | 9.60 | 10.20 | 9.71 | 9.96 | 9.99 |
| Alk | 91.5 | 119.6 | 56.4 | 48.3 | 39.1 | 52.9 | 57.7 | 50.6 |
| Turb (NTU) | 21.0 | 32.8 | 31.9 | 30.3 | 28.0 | 33.5 | 36.3 | 15.7 |
| Ammonia-N | 0.07 | 1.13 | 0.11 | 0.14 | 0.19 | 0.05 | 0.11 | 0.04 |
| Diss solids | 401 | 436 | 475 | 479 | 503 | 575 | 569 | 543 |
| Susp solids | 72 | 140 | 114 | 110 | 148 | 100 | 148 | 50 |
| T phos | 0.40 | 0.39 | 0.38 | 0.29 | 0.36 | 0.33 | 0.37 | 0.23 |
| Diss phos | 0.00 | 0.03 | 0.06 | 0.03 | 0.01 | 0.05 | 0.02 | 0.07 |

| | Sep 13-14 | Sep 27-28 | Oct 11-12 | Oct 25-26 | Nov 15-16 | Nov 29-30 | Dec 13-14 | Jan 8-9 | Jan 22-23 |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|------------|--------------|
| Secchi (in) | 5 | 7 | 10 | 9 | 29 | 25 | 22 | 20 | 14 |
| pH (units) | 9.90 | 9.53 | 8.63 | 8.68 | 8.24 | 8.27 | 8.51 | 7.67 | 8.10 |
| Alk | 53.3 | 47.2 | 91.2 | 102.5 | 115.0 | 118.9 | 142.5 | 156.8 | 166.1 |
| Turb (NTU) | 37.3 | 25.2 | 13.6 | 11.0 | 7.1 | 3.9 | 3.6 | 5.4 | 9.7 |
| Ammonia-N | 0.19 | 0.05 | 0.47 | 0.66 | 0.68 | 0.71 | 0.73 | 0.48 | 1.27 |
| Diss solids | 623 | 591 | 652 | 631 | 585 | 592 | 597 | 643 | 649 |
| Susp solids | 71 | 51 | 33 | 49 | 13 | 3 | 12 | 23 | 14 |
| T phos | 0.28 | 0.17 | 0.12 | 0.14 | 0.12 | 0.10 | 0.06 | 0.12 | 0.11 |
| Diss phos | 0.04 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.05 | 0.03 | 0.02 |

Residual chlorine 0

Appendix B-1. Concluded

Station 8

| | May 24-25 | Jun 7-8 | Jun 21-22 | Jul 5-6 | Jul 18-19 | Aug 2-3 | Aug 15-16 | Aug 30-31 |
|-------------|--------------|------------|--------------|------------|--------------|------------|--------------|--------------|
| Secchi (in) | 9 | 5 | 4 | 5 | 4 | 3 | 4 | 5 |
| pH (units) | 9.05 | 8.21 | 9.15 | 9.40 | 9.79 | 9.30 | 9.49 | 9.59 |
| Alk | 67.2 | 130.0 | 71.3 | 64.4 | 57.5 | 65.6 | 66.7 | 60.5 |
| Turb (NTU) | 12.1 | 44.0 | 30.3 | 36.3 | 40.0 | 39.4 | 45.0 | 18.0 |
| Ammonia-N | 0.04 | 1.77 | 0.12 | 0.14 | 0.12 | 0.05 | Tr | 0.04 |
| Diss solids | 441 | 515 | 532 | 511 | 558 | 548 | 542 | 620 |
| Susp solids | 53 | 213 | 170 | 178 | 266 | 222 | 174 | 70 |
| T phos | 0.22 | 0.32 | 0.33 | 0.38 | 0.42 | 0.33 | 0.47 | 0.30 |
| Diss phos | 0.02 | 0.02 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 | 0.11 |

| | Sep 13-14 | Sep 27-28 | Oct 11-12 | Oct 25-26 | Nov 15-16 | Nov 29-30 | Dec 13-14 | Jan 8-9 | Jan 22-23 |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|------------|--------------|
| Secchi (in) | 5 | 6 | 8 | 9 | 18 | 23 | 28 | 24+ | 24+ |
| pH (units) | 9.51 | 9.50 | 8.68 | 8.50 | 8.29 | 8.25 | 8.30 | 7.80 | 7.40 |
| Alk | 59.5 | 57.4 | 87.1 | 112.8 | 111.0 | 121.2 | 129.2 | 155.8 | 162.0 |
| Turb (NTU) | 39.3 | 30.8 | 17.4 | 15.0 | 4.5 | 4.4 | 3.2 | 3.0 | 3.9 |
| Ammonia-N | 0.30 | 0.02 | 0.12 | 0.50 | 0.56 | 0.88 | 0.78 | 0.85 | 1.20 |
| Diss solids | 615 | 625 | 660 | 616 | 600 | 622 | 611 | 663 | 663 |
| Susp solids | 96 | 71 | 52 | 64 | 15 | 11 | 9 | 9 | 4 |
| T phos | 0.28 | 0.23 | 0.17 | 0.15 | 0.10 | 0.07 | 0.07 | 0.06 | 0.03 |
| Diss phos | 0.08 | 0.02 | 0.04 | 0.03 | 0.03 | 0.02 | 0.01 | 0.01 | 0.02 |

Residual chlorine 0

Station 9

| | May 24-25 | Jun 7-8 | Jun 21-22 | Jul 5-6 | Jul 18-19 | Aug 2-3 | Aug 15-16 | Aug 30-31 |
|-------------|--------------|------------|--------------|------------|--------------|------------|--------------|--------------|
| Secchi (in) | 5 | 4 | 5 | 3 | 4 | 4 | 6 | 8 |
| pH (units) | 8.88 | 8.20 | 9.00 | 8.82 | 9.48 | 9.21 | 9.08 | 8.05 |
| Alk | 68.5 | 128.8 | 78.2 | 43.5 | 57.5 | 55.2 | 77.7 | 92.3 |
| Turb (NTU) | 14.2 | 36.0 | 30.3 | 48.7 | 39.1 | 38.3 | 37.0 | 14.6 |
| Ammonia-N | 0.05 | 1.73 | 0.27 | 0.19 | 0.22 | 0.02 | Tr | 0.47 |
| Diss solids | 450 | 511 | 537 | 606 | | 520 | 645 | 640 |
| Susp solids | 145 | 65 | 90 | 551 | 152 | 284 | 132 | 69 |
| T phos | 0.35 | 0.35 | 0.34 | 0.70 | 0.51 | 0.37 | 0.43 | 0.35 |
| Diss phos | 0.03 | 0.02 | 0.02 | 0.01 | 0.03 | 0.05 | 0.01 | 0.05 |

| | Sep 13-14 | Sep 27-28 | Oct 11-12 | Oct 25-26 | Nov 15-16 | Nov 29-30 | Dec 13-14 | Jan 8-9 | Jan 22-23 |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|------------|--------------|
| Secchi (in) | 6 | 12 | 9 | 8 | 12 | 24 | 30 | 36+ | 36+ |
| pH (units) | 8.00 | 7.55 | 7.53 | 7.77 | 7.95 | 8.13 | 8.34 | 7.75 | 7.37 |
| Alk | 86.1 | 96.4 | 99.4 | 98.4 | 112.0 | 120.0 | 125.1 | 157.9 | 164.0 |
| Turb (NTU) | 34.6 | 56.1 | 9.7 | 17 | 7.2 | 3.6 | 3.2 | 4.2 | 4.7 |
| Ammonia-N | 0.50 | 0.69 | 0.88 | 0.57 | 0.66 | 0.88 | 0.76 | 0.76 | 1.03 |
| Diss solids | 638 | 633 | 684 | 647 | 616 | 617 | 606 | 691 | 693 |
| Susp solids | 127 | 42 | 32 | 156 | 36 | 15 | 10 | 13 | 5 |
| T phos | 1.35* | 0.29 | 0.16 | 0.27 | 0.14 | 0.09 | 0.06 | 0.04 | 0.03 |
| Diss phos | 0.81* | 0.03 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |

* Questionable, not included in computations

Residual chlorine 0

Appendix B-2. Water Quality Characteristics, Ranges and Means, Horseshoe Lake

| | Station 1 | | | Station 2 | | |
|---------------------------------|----------------|------|--------------|----------------|------|--------------|
| | No. of samples | Mean | Range | No. of samples | Mean | Range |
| DO | 17 | 13.7 | (6.3-20+)* | 17 | 8.7 | (5.8-11.1) |
| Temp (°C) | 17 | 21.0 | (0.8-34.0)* | 17 | 18.1 | (1.2-29.3) |
| Secchi (in) | 16 | 7 | (3-22+) | 17 | 21 | (5-53) |
| pH (units) | 17 | | (7.61-10.41) | 17 | | (7.29-9.92) |
| Alkalinity | 17 | 83.5 | (48.1-129.2) | 17 | 92.9 | (39.3-166.1) |
| Turbidity (NTU) | 17 | 32.4 | (7.2-68.3) | 17 | 11.1 | (1.2-33.3) |
| Ammonia-N | 17 | 0.18 | (0.00-0.68) | 17 | 0.67 | (0.03-2.19) |
| Dissolved solids | 17 | 532 | (319-721) | 17 | 662 | (556-778) |
| Suspended solids | 17 | 188 | (6-564) | 17 | 42 | (3-192) |
| Total phosphorus | 17 | 0.95 | (0.10-3.17) | 17 | 0.12 | (0.02-0.25) |
| Dissolved phosphorus | 17 | 0.19 | (0.01-1.93) | 17 | 0.03 | (Trace-0.10) |
| Benthos (indiv/m ²) | 9 | 1006 | (85-3502) | 9 | 1281 | (805-2038) |
| Algae (cts/ml) | 17 | 9148 | (81-213,202) | 17 | 5792 | (0-7250) |
| Zooplankton (cts/l) | | | | 17 | 2003 | (88-59,744) |

* At surface

| | Station 3 | | | Station 4 | | |
|---------------------------------|----------------|-------|--------------|----------------|-------|--------------|
| | No. of samples | Mean | Range | No. of samples | Mean | Range |
| DO | 17 | 7.9 | (5.5-12.3) | 17 | 7.9 | (5.4-10.8)* |
| Temp (°C) | 17 | 19.6 | (1.5-31.9) | 17 | 17.9 | (0.3-29.5)* |
| Secchi (in) | 17 | 24 | (9-48+) | 17 | 12 | (6-25+) |
| pH (units) | 17 | | (6.96-8.50) | 17 | | (7.15-9.21) |
| Alkalinity | 17 | 126.6 | (89.7-147.2) | 17 | 113.6 | (49.5-174.3) |
| Turbidity (NTU) | 17 | 7.0 | (1.5-21.0) | 17 | 16.0 | (3.9-39.2) |
| Ammonia-N | 17 | 0.64 | (0.16-1.58) | 17 | 0.50 | (0.11-1.53) |
| Dissolved solids | 17 | 711 | (587-813) | 17 | 577 | (343-752) |
| Suspended solids | 17 | 29 | (1-200) | 17 | 62 | (9-202) |
| Total phosphorus | 17 | 0.07 | (0.02-2.40) | 17 | 0.23 | (0.07-0.44) |
| Dissolved phosphorus | 17 | 0.02 | (Trace-2.39) | 17 | 0.03 | (Trace-0.06) |
| Benthos (indiv/m ²) | 9 | 377 | (14-817) | 9 | 589 | (129-1464) |
| Algae (cts/ml) | 17 | 2655 | (0-27,482) | 17 | 5705 | (56-112,507) |
| Zooplankton (cts/l) | 16 | 775 | (0-2550) | | | |

* At surface

| | Station 5 (top) | | | Station 5 (5 feet above bottom) | | |
|---------------------------------|--------------------|-------|--------------|------------------------------------|-------|--------------|
| | No. of samples | Mean | Range | No. of samples | Mean | Range |
| DO | 17 | 8.0 | (5.4-15+) | 17 | 3.8 | (0.0-11.8) |
| Temp (°C) | 17 | 18.3 | (1.5-30.2) | 17 | 12.7 | (2.3-20.0) |
| Secchi (in) | 17 | 16 | (7-42) | NA | NA | NA |
| pH (units) | 17 | | (7.04-9.52) | 17 | | (7.03-8.39) |
| Alkalinity | 17 | 100.6 | (46.5-155.8) | 17 | 157.4 | (86.1-244.0) |
| Turbidity (NTU) | 17 | 11.0 | (3.9-21.9) | 17 | 13.6 | (4.4-29.3) |
| Ammonia-N | 17 | 0.57 | (0.09-1.54) | 17 | 1.64 | (0.39-3.57) |
| Dissolved solids | 17 | 607 | (494-683) | 17 | 570 | (460-745) |
| Suspended solids | 17 | 27 | (1-54) | 17 | 35 | (1-130) |
| Total phosphorus | 17 | 0.13 | (0.04-0.24) | 17 | 0.19 | (0.03-0.52) |
| Dissolved phosphorus | 17 | 0.03 | (0.01-0.06) | 17 | 0.02 | (0.01-0.07) |
| Benthos (indiv/m ²) | | | | 9 | 907 | (287-1966) |
| Algae (cts/ml) | 17 | 4677 | (44-55,754) | 17 | 2761 | (22-33,966) |
| Zooplankton (cts/l) | 17 | 2401 | (0-9700) | | | |

Note: NA = not applicable

Note: Concentrations in mg/l unless otherwise indicated

Appendix B-2, Concluded

| | Station 6 | | | Station 7 | | |
|---------------------------------|----------------|------|--------------|----------------|------|--------------|
| | No. of samples | Mean | Range | No. of samples | Mean | Range |
| DO | 17 | 10.3 | (5.3-13.2) | 17 | 11.2 | (7.5-14.5) |
| Temp (°C) | 17 | 18.8 | (1.7-31.0) | 17 | 19.0 | (1.2-31.3) |
| Secchi (in) | 17 | 12 | (4-34) | 17 | 11 | (5-29) |
| pH (units) | 17 | | (6.65-10.14) | 17 | | (7.67-10.20) |
| Alkalinity | 17 | 98.6 | (55.4-194.8) | 17 | 89.6 | (39.1-166.1) |
| Turbidity (NTU) | 17 | 18.3 | (3.0-39.2) | 17 | 20.4 | (3.6-37.3) |
| Ammonia-N | 17 | 0.34 | (0.02-0.85) | 17 | 0.42 | (0.04-1.27) |
| Dissolved solids | 17 | 544 | (359-699) | 17 | 561 | (401-652) |
| Suspended solids | 17 | 56 | (7-136) | 17 | 68 | (3-148) |
| Total phosphorus | 17 | 0.24 | (0.11-0.37) | 17 | 0.23 | (0.06-0.40) |
| Dissolved phosphorus | 17 | 0.02 | (0.01-0.07) | 17 | 0.03 | (0.00-0.07) |
| Benthos (indiv/m ²) | 9 | 851 | (293-1951) | 9 | 944 | (531-1837) |
| Algae (cts/ml) | 17 | 5427 | (37-55,912) | 17 | 7817 | (33-99,750) |
| Zooplankton (cts/l) | | | | 17 | 2682 | (0-11,650) |

| | Station 8 | | | Station 9 | | |
|---------------------------------|----------------|------|--------------|----------------|------|--------------|
| | No. of samples | Mean | Range | No. of samples | Mean | Range |
| DO | 17 | 10.8 | (6.5-15+)* | 17 | 8.8 | (2.7-13.6) |
| Temp (°C) | 17 | 19.0 | (1.9-31.0)* | 17 | 20.0 | (2.0-34.8) |
| Secchi (in) | 17 | 11 | (3-28) | 17 | 12 | (3-36+) |
| pH (units) | 17 | | (7.40-9.79) | 17 | | (7.37-9.48) |
| Alkalinity | 17 | 96.5 | (57.4-174.3) | 17 | 97.7 | (43.5-164.0) |
| Turbidity (NTU) | 17 | 22.7 | (3.0-45.0) | 17 | 23.4 | (3.2-48.7) |
| Ammonia-N | 17 | 0.42 | (Trace-1.77) | 17 | 0.57 | (Trace-1.73) |
| Dissolved solids | 17 | 585 | (441-663) | 17 | 608 | (450-693) |
| Suspended solids | 17 | 99 | (4-266) | 17 | 113 | (5-551) |
| Total phosphorus | 17 | 0.23 | (0.03-0.47) | 17 | 0.34 | (0.03-1.35) |
| Dissolved phosphorus | 17 | 0.03 | (0.01-0.11) | 17 | 0.07 | (0.01-0.81) |
| Benthos (indiv/m ²) | 9 | 1295 | (459-2871) | | | |
| Algae (cts/ml) | 17 | 6649 | (40-144,164) | | | |
| Zooplankton (cts/l) | | | | | | |

* At surface

Appendix C-1. Nocturnal Dissolved Oxygen and Water Temperature
at Five Stations in Horseshoe Lake, August 16-17, 1978

| | Station 2 | | | Station 3 | | | Station 4 | | |
|------|-----------|--------|--------|-----------|--------|--------|-----------|--------|--------|
| | 8:45pm | 1:45am | 4:50am | 8:40pm | 1:35am | 4:45am | 8:25pm | 1:25am | 4:30am |
| Temp | 27.8 | 26.5 | 26.0 | 28.2 | 27.5 | 27.5 | 28.8 | 25.1 | 25.6 |
| DO | 12.0 | 10.1 | 8.5 | 8.6 | 7.1 | 6.3 | 13.2 | 8.4 | 6.0 |

| | Station 6 | | | Station 7 | | |
|------|-----------|---------|--------|-----------|---------|--------|
| | 7:30pm | 11:45pm | 2:35am | 7:25pm | 11:35am | 2:25am |
| Temp | 29.0 | 27.0 | 26.0 | 28.2 | 26.3 | 25.7 |
| DO | 14.0 | 9.7 | 8.4 | 15.4 | 11.6 | 8.8 |

Appendix C-2. Nocturnal Water Temperature at Station 5, Horseshoe Lake,
August 16-17, 1978

| | 6pm | 7pm | 8pm | 9pm | 10pm | 11pm | 12mid | 1am | 2am | 3am | 4am | 5am | 6am |
|--------------|------|------|------|------|------|------|-------|------|------|------|------|------|------|
| Temp at 0 ft | 28.5 | 28.5 | 27.8 | 27.3 | 27.0 | 26.9 | 27.1 | 26.5 | 26.8 | 26.5 | 26.1 | 26.6 | 26.0 |
| 1 | 28.2 | 28.4 | 28.0 | 27.6 | 27.1 | 27.3 | 27.2 | 26.7 | 26.8 | 26.9 | 27.0 | 26.7 | 26.8 |
| 2 | 28.1 | 28.4 | 28.0 | 27.6 | 27.1 | 27.3 | 27.3 | 26.9 | 27.0 | 26.9 | 27.0 | 26.8 | 26.8 |
| 3 | 28.0 | 28.2 | 28.0 | 27.9 | 27.2 | 27.3 | 27.5 | 26.9 | 27.0 | 27.0 | 27.0 | 26.8 | 26.8 |
| 4 | 28.0 | 28.2 | 28.0 | 27.9 | 27.2 | 27.4 | 27.4 | 26.9 | 27.1 | 27.0 | 27.0 | 27.0 | 26.8 |
| 5 | 27.8 | 27.9 | 27.6 | 27.9 | 27.2 | 27.5 | 27.5 | 26.9 | 27.1 | 27.0 | 27.0 | 26.9 | 26.8 |
| 6 | 27.1 | 27.5 | 27.2 | 27.8 | 27.2 | 27.4 | 27.4 | 26.8 | 27.0 | 27.0 | 27.0 | 26.8 | 26.8 |
| 7 | 26.9 | 27.2 | 27.0 | 27.2 | 27.2 | 27.3 | 27.2 | 26.7 | 27.0 | 27.0 | 27.0 | 26.8 | 25.7 |
| 8 | 26.5 | 26.9 | 26.9 | 27.0 | 27.0 | 27.0 | 27.0 | 26.5 | 27.0 | 27.0 | 27.0 | 26.7 | 25.5 |
| 9 | 26.3 | 26.6 | 26.3 | 26.7 | 26.3 | 26.4 | 26.8 | 26.2 | 26.9 | 26.9 | 26.8 | 26.6 | 26.4 |
| 10 | 26.2 | 26.2 | 26.0 | 26.2 | 26.0 | 26.1 | 26.2 | 26.0 | 26.4 | 26.5 | 26.5 | 26.5 | 26.2 |
| 12 | 25.7 | 25.3 | 25.4 | 25.5 | 25.2 | 25.5 | 25.8 | 25.5 | 25.8 | 25.8 | 25.9 | 25.8 | 25.8 |
| 14 | 24.8 | 25.0 | 25.0 | 25.0 | 24.9 | 25.0 | 25.1 | 25.0 | 25.1 | 25.1 | 25.1 | 25.2 | 25.0 |
| 20 | 21.9 | 22.1 | 22.0 | 22.0 | 22.0 | 22.0 | 21.5 | 21.9 | 22.1 | 22.0 | 22.0 | 22.2 | 22.2 |
| 30 | 17.7 | 18.1 | 18.0 | 18.0 | 18.0 | 17.8 | 17.5 | 17.8 | 17.9 | 18.0 | 18.0 | 18.0 | 18.0 |
| 38 | 16.8 | 17.0 | 17.5 | 17.0 | 16.5 | 17.0 | 16.5 | 16.8 | 17.1 | 16.9 | 17.0 | 17.0 | 17.2 |

Appendix C-3. Nocturnal Dissolved Oxygen and Weather at Station 5,
Horseshoe Lake, August 16-17, 1978
(Sunset 7:50 a.m. - Sunrise 6:20 p.m.)

| | 6pm | 7pm | 8pm | 9pm | 10pm | 11pm | 12mid | 1am | 2am | 3am | 4am | 5am | 6am |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Weather | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear | Clear |
| Air temp | 29.5 | 29.1 | 27.2 | 24.4 | 24.1 | 24.0 | 23.1 | 23.2 | 20.5 | 21.1 | 21.4 | 21.6 | 22.4 |
| DO at 0 ft | 9.4 | 9.2 | 9.0 | 8.6 | 7.5 | 7.2 | 6.8 | 6.3 | 5.8 | 5.2 | 4.8 | 4.6 | 4.2 |
| 1 | 9.3 | 9.2 | 9.0 | 8.5 | 7.5 | 7.2 | 6.8 | 6.2 | 5.7 | 5.1 | 4.7 | 4.4 | 4.2 |
| 2 | 9.1 | 9.1 | 9.0 | 8.4 | 7.5 | 7.1 | 6.7 | 6.2 | 5.7 | 5.1 | 4.6 | 4.3 | 4.1 |
| 3 | 9.0 | 9.0 | 8.9 | 8.3 | 7.4 | 7.1 | 6.6 | 6.3 | 5.6 | 5.1 | 4.6 | 4.3 | 4.1 |
| 4 | 8.7 | 8.6 | 8.6 | 8.2 | 7.4 | 7.0 | 6.3 | 6.2 | 5.6 | 5.1 | 4.6 | 4.3 | 4.1 |
| 5 | 7.6 | 6.8 | 6.6 | 8.2 | 7.4 | 7.0 | 6.5 | 6.2 | 5.5 | 5.1 | 4.6 | 4.2 | 4.1 |
| 6 | 5.9 | 6.2 | 6.0 | 6.8 | 7.3 | 6.9 | 6.4 | 6.0 | 5.3 | 5.1 | 4.6 | 4.1 | 3.8 |
| 7 | 5.8 | 6.0 | 5.8 | 5.8 | 6.6 | 6.3 | 5.7 | 5.6 | 4.6 | 5.0 | 4.6 | 4.1 | 3.8 |
| 8 | 5.2 | 4.8 | 4.9 | 5.1 | 5.0 | 4.9 | 4.2 | 4.1 | 4.3 | 4.9 | 4.5 | 4.0 | 3.5 |
| 9 | 4.5 | 4.1 | 3.7 | 3.9 | 3.2 | 3.0 | 3.2 | 2.7 | 3.4 | 4.7 | 4.1 | 4.0 | 3.3 |
| 10 | 4.2 | 2.8 | 2.4 | 2.6 | 2.2 | 1.9 | 2.2 | 2.1 | 2.2 | 2.8 | 3.8 | 3.6 | 2.9 |
| 12 | 1.9 | 0.7 | 0.7 | 0.6 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.2 | 0.4 |
| 14 | 0.5 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 20 | 0.5 | 0.4 | 0.4 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 30 | 0.5 | 0.4 | 0.4 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 0.2 |
| 38 | 0.5 | 0.4 | 0.4 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |

Note: Temperature In degrees Celsius; dissolved oxygen in mg/l

Appendix D. Occurrence and Type of Algae at Sampling Locations
(Counts per milliliter of water)

| | May 25 | | | | | | | | June 8 | | | | | | | | | |
|----------------------------------|--------|------|------|-------|-------|-------|-------|-------|--------|------|------|-----|-----|------|-------|------|------|-------|
| | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 |
| Blue-green algae | | | | | | | | | | | | | | | | | | |
| <i>Anabaena flos-aquae</i> | | | | | | | | | | | | | | | | | | |
| <i>A. spiroides</i> | | | | | | | | | | | | | | | | | | |
| <i>Anacystis cyanea</i> | | | 630 | | | | | | | | | | | | | | | 16695 |
| <i>A. chroocolla</i> | | | | | | | | | | | | | | | | | | |
| <i>Aphanizomenon flos-aquae</i> | 5985 | 840 | 3203 | 1103 | | | | | | | | | | | | | 9765 | 10133 |
| <i>Arthrospira Jenneri</i> | | | | | | | | | | | | | | | | | | |
| <i>Oscillatoria angustissima</i> | | | | 10920 | 42053 | 14910 | 15560 | 10920 | 13803 | | | | | | 10553 | | | |
| <i>O. chlorina</i> | | | | | | | | | | | | | | | | | | |
| <i>O. puerida</i> | | | | | | | | | | | | | | | | | | |
| <i>Spiculinia hordsedtii</i> | | | | | | | | | | | | | | | | | | |
| Green algae | | | | | | | | | | | | | | | | | | |
| <i>Actinastrum Hantzschii</i> | 6878 | | | 735 | | | | | 630 | | | | | | | | | |
| <i>Ankistrodesmus convolutus</i> | | | | | | | | | | | | | | | | | | |
| <i>A. falcatus</i> | | 893 | | | | | | | 378 | | | | | | | | | |
| <i>Chlorella ellipsoidea</i> | | | | | | | | | | 3045 | | | 212 | | | | | |
| <i>Coelastrum microporum</i> | | | | | | | | | | | | | | | | | | |
| <i>Crucigenia rectangularis</i> | | | 893 | | | | | | | | | | | | | | | |
| <i>Coocystis Borgesi</i> | | | | | | | | | | | | | | | | | | |
| <i>Pediastrum duplex</i> | | | | | | | | | | 1102 | | 244 | | | | 1050 | | |
| <i>P. simplex</i> | | 945 | | | | | | | | | | | | | | 2258 | 860 | |
| <i>Scenedesmus catenatus</i> | | | | | | | | | | 3202 | | | | | | | | |
| <i>S. dimorphus</i> | 4673 | 5826 | 4778 | 1050 | 2153 | 6878 | 1103 | | | 2572 | | | | | | | | |
| <i>S. quadricauda</i> | 1155 | | | | | | | | | | | | | | | | | |
| <i>Spora ovalis</i> | | | | | | | | | | | | | | | | | | |
| <i>Ulothrix variabilis</i> | | 893 | | 683 | 4253 | | | | 1628 | | | | | | | | | |
| <i>U. zonata</i> | | | | | | | | | | | | | | | | | | |
| Diatoms | | | | | | | | | | | | | | | | | | |
| <i>Coloneis amphibiaena</i> | | | | | | | | | | | | | | | | | | |
| <i>Cyclotella meneghiniana</i> | | | | | | | | | | 1103 | | | 228 | | 2258 | 840 | | |
| <i>C. ocellata</i> | | | | | | | | | | | | | | | | | | |
| <i>Cyanocoleus solus</i> | | | | | | | | | | | | | | | | | | |
| <i>Cymbella prostrata</i> | | | | | | | | | | | | 32 | | | | | | |
| <i>Fragilaria capricornis</i> | | | | | | | | 53 | | | | | | | | | | |
| <i>Comphonema olivaceum</i> | | | | | | | | | | 840 | | | | | | | | |
| <i>Gyrodinium aureolum</i> | | | | | | | | | | | | | | | | | | |
| <i>G. vermiculatum</i> | | | | | | | | | | | | | | | | | | |
| <i>Hantzschia amphioxys</i> | | | | | | | | | | | | | | | | | | |
| <i>Melosira granulata</i> | | | | | | | 1995 | | | | | | | | | | 1365 | |
| <i>Navicula canalis</i> | | | | | | | | | | | | | | | | | | |
| <i>N. cryptocephala</i> | | | | | | | | | | | | | | | | | | |
| <i>N. cuspidata</i> | 210 | | | | | | | | | | | | | | | | | |
| <i>N. gaudium</i> | | | | | | | | | | | | | | | | | | |
| <i>N. graciloides</i> | | | | | | | | | | | | | 196 | | | | 2678 | 1418 |
| <i>N. odiosa</i> | | | | | | | | | | | | | | | | | 3203 | |
| <i>N. radiosa</i> | | | | | | | | | | | | | | | | | | |
| <i>N. setiformis</i> | | | | | | | | | | | | | | | | | | |
| <i>N. saxoni</i> | | | | | | | | | | | | | | | | | | |
| <i>Neidium dubium</i> | | | | | | | | | | | | 27 | | | | | | |
| <i>Nitzschia ocellularis</i> | | | | | | | | | | | | | | | | | | |
| <i>N. angustata</i> | | | | | | | | | | | | | | | | | | |
| <i>N. zigzag</i> | | | | | | | | 215 | | | | | | | | | | |
| <i>N. tryblionella</i> | | | | | | | | | | | | | | | | | | |
| <i>Finlayella caudata</i> | | | | | | | | | | | | | | | | | | |
| <i>Surirella angustata</i> | | | | | | | | | | | | | | | | | | |
| <i>S. ovata</i> | | | | | | | | | | | | | | | | | | |
| <i>S. robusta</i> | | | | | | | | | | 5723 | | | | | 3728 | | 998 | |
| <i>S. saronica</i> | | | | | | | | | | | | | | | | | | |
| <i>Synedra acus</i> | | | | | | | | | | | | | | | | | | |
| <i>S. acuta</i> | | | | | | | | | | | | | | | | | | |
| <i>S. delicatissima</i> | 49402 | 7560 | 7665 | 14070 | 7403 | 8875 | 12653 | 10028 | 5303 | 8453 | 270 | | | | 10343 | | 2048 | |
| <i>S. nana</i> | | | | | | | | | | | | | | | | | | |
| <i>S. rumpens</i> | | | | | | | | | | | | | | | | | | |
| <i>S. ulna</i> | | | | | | | | | 2625 | | | | | | | | | |
| Flagellates | | | | | | | | | | | | | | | | | | |
| <i>Detonula multifida</i> | | | | | | | | | | | | | | | | | | |
| <i>Chlamydomonas reinhardtii</i> | | | | | | | | | | | | | | | | | | |
| <i>Euglena gracilis</i> | | | | | | | | | | 1628 | 148 | | | | | | | |
| <i>E. oxyuris</i> | | | | | | | | | | | | | | | | | | |
| <i>E. viridis</i> | | | | | | | | | | | | | | | | | | |
| <i>Phacus pleuropectus</i> | | | | 53 | | | | | | 210 | 2415 | | | | 210 | | 1995 | |
| <i>Trachomonas croceus</i> | | | | | | | | | | | | | | | | | | |
| Others | | | | | | | | | | | | | | | | | | |
| <i>Closterium</i> sp. | | | | | | | | | | 7403 | | | | 1470 | | | | |
| <i>Coelastrum</i> sp. | | | | | | | | | | | | | | | | | | |
| <i>Staurastrum cornutum</i> | | 840 | | | | | | | | 1628 | | | | | | | 473 | |

Appendix D. Continued

| | July 19 | | | | | | | | August 3 | | | | | | | | | | |
|----------------------------------|---------|------|------|------|-------|------|-------|-------|----------|------|-------|------|-------|-------|------|-------|-------|-------|------|
| | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 | |
| Blue-green Algae | | | | | | | | | | | | | | | | | | | |
| <i>Anabaena flos-aquae</i> | | | | | | | | | | | | | | | | | | | 998 |
| <i>A. spiroides</i> | 3203 | 2678 | 1943 | 3303 | 3203 | 5933 | 5303 | 11340 | 11340 | 7193 | | | | | | | | | |
| <i>Anacystis cyanea</i> | | | | | | | | | | | | | | | | | | | |
| <i>A. thomalis</i> | | | | | | | | | | | | | | | | | | | |
| <i>Aphanisomenon flos-aquae</i> | 4095 | | 2153 | 5093 | 21945 | 2068 | 20503 | 21420 | 21158 | 9503 | 15803 | 4883 | 13703 | 43628 | 6615 | 50453 | 58065 | 37433 | |
| <i>Arthrospira Jemotii</i> | | | | | | | | | | | | | 2415 | 3570 | | | | | |
| <i>Oscillatoria angustissima</i> | | | | | | | | | | | | | 3729 | | | | | | |
| <i>O. chlorina</i> | | | | | | | | | | | | 1365 | | | | | | | |
| <i>O. putrida</i> | | | | | | | | | | | | | | | | | | | |
| <i>Spirulina Mordstedtii</i> | | | | | | | | | | | | | | | | | | | |
| Green algae | | | | | | | | | | | | | | | | | | | |
| <i>Actinastrum Mantschlii</i> | | | | | | | | | | | | | | | | | | | |
| <i>Ankistrodesmus convolutus</i> | | | | | | | | | | | | | | | | | | | |
| <i>A. falcatus</i> | | | | | | | | | | | | | | | | | | | |
| <i>Chlorella ellipsoidea</i> | | | | | 3308 | | | 2520 | 2678 | | | | | | | | | | |
| <i>Coelastrum microporum</i> | | | | | | | | | | | | | | | | | | | |
| <i>Crocodygia rectangularis</i> | | | | | | | | | | | | | | | | | | | |
| <i>Coccytis Borgesi</i> | | 3518 | 998 | | | | 420 | | | 420 | 840 | | | | | | | | |
| <i>Podiastrum duplex</i> | 891 | 3728 | | 1050 | | | 998 | 1103 | | 578 | | 1420 | | | | | | | |
| <i>P. simplex</i> | | | | | | | | | | | | | | | | | | | |
| <i>Scenedesmus carinatus</i> | | | | | | | | | | 1575 | | | 1890 | | | | | | |
| <i>S. dimorphus</i> | | | | | | | | | | | | | 2258 | | | | | | |
| <i>S. quadricauda</i> | | | | | | | | | | | | | | | | | | | |
| <i>Synura uvella</i> | | | | | | | | | | | | | | | | | | | |
| <i>Ulothrix variabilis</i> | | | | | | | | | | | | | | | | | | | |
| <i>U. sonata</i> | | | | 1890 | | | | | | | | | 1470 | | | | | | |
| Diatoms | | | | | | | | | | | | | | | | | | | |
| <i>Caloneis amphibaena</i> | | | | | | | | | | | | | | | | | | | 158 |
| <i>Cyclotella meneghiniana</i> | | | 840 | | | | 840 | | | 525 | | | | | | 578 | | | 210 |
| <i>C. scollata</i> | | | | | | | | 2678 | | | | | | | | | | | |
| <i>Cymbella solea</i> | | | | | | | | | | | | | | | | | | | |
| <i>Cymbella prostrata</i> | | | | | | | | | | | | | | | | | | | |
| <i>Fragularia capucina</i> | | | | | | | | | | | | | | | | | | | |
| <i>Gomphonema olivaceum</i> | | | | | | | | | | | | | | | | | | | |
| <i>Gyrosigma mucron</i> | | | | | | | | | | | | | | | | | | | |
| <i>G. wernleyi</i> | | | | | | | | | | | | | | | | | | | |
| <i>Mantzschia amphioxys</i> | | | | | | | | | | | | | | | | | | | |
| <i>Nitzschia granulata</i> | | | | | 1050 | | | | | | | | 1103 | 883 | 2680 | | | 1103 | |
| <i>Nitzschia canalis</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. cryocrocephala</i> | 210 | | | | | | | | | | | | | | | | | | |
| <i>N. cuspidata</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. gastrum</i> | | | | | | | | | | | | | | | | | | | 1050 |
| <i>N. graciloides</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. odiosa</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. radiosa</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. salinarum</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. taroni</i> | | | | | | | | | | | | | | | | | | | |
| <i>Nitzschia dubium</i> | | | | | | | | | | | | | | | | | | | |
| <i>Nitzschia aciculata</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. angustata</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. sigma</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. tryblionella</i> | | | | | | | | | | | | | | | | | | | |
| <i>Pinnularia caudata</i> | | | | | | | | | | | | | | | | | | | |
| <i>Surirella angustata</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. ovata</i> | | | | | 998 | | | | | | | | | | 368 | | | | |
| <i>S. robusta</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. serotica</i> | | | | | | | | | | | | | | | | | | | |
| <i>Synedra acus</i> | 525 | 1523 | 1155 | | | | 1155 | 578 | 1680 | 1575 | | 1943 | | | | | | 368 | |
| <i>S. acuta</i> | | | | 5670 | | | | | | | | | | | | | | | |
| <i>S. dolicatissima</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. nana</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. rumpens</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. ulna</i> | | | | | | | | | | | | | | | | | | | |
| Flagellates | | | | | | | | | | | | | | | | | | | |
| <i>Cartesia multifilis</i> | | | | | | | | | | | | | | | | | | | |
| <i>Chlamydomonas reinherdi</i> | | | | | | | | | | | | | | | | | | | |
| <i>Euplena gracilis</i> | | | | | | | | | | | | | | | | | | | |
| <i>E. oxyuris</i> | | | | | | | | | | | | | | | | | | | 210 |
| <i>E. vicidii</i> | 1523 | 788 | 735 | 1103 | 420 | 893 | | 420 | | 945 | | | | | | | | 53 | |
| <i>Phacus pleuronectus</i> | | | | | | | | | | | | | | | | | | | |
| <i>Trachelomonas crobbe</i> | | | | | | | | | | | | | | | | 158 | | | |
| Othors | | | | | | | | | | | | | | | | | | | |
| <i>Closterium</i> sp. | | | | | | | | | | | | | | | | | | | |
| <i>Coelastrum</i> sp. | | | | | | | | | | | | | | | | | | | |
| <i>Staurastrum cornutum</i> | | | | | | | | | | | | | | | | | | | |

Appendix D. Continued

| | September 14 | | | | | | | | September 28 | | | | | | | | | | |
|----------------------------------|--------------|-------|-------|------|------|------|-------|-------|--------------|-------|-------|-------|------|------|------|-------|-------|-------|-----|
| | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 | |
| Blue-green algae | | | | | | | | | | | | | | | | | | | |
| <i>Anabaena flos-aquae</i> | 10341 | | | | | | | | | | | | | | | | | | |
| <i>A. spiroides</i> | | 5303 | | | | | 998 | | 840 | 2150 | 4358 | | | | | | | | |
| <i>Anacystis cyanus</i> | | | | | | | | | | | | | | | | | | | |
| <i>A. cherealis</i> | | | | | | | | | | | | | | | | | | | |
| <i>Aphanizomenon flos-aquae</i> | | 48878 | 26400 | 5040 | 5566 | 2048 | 47565 | 18118 | 20423 | 2153 | 42368 | 17903 | 8715 | 7140 | 1098 | 37118 | 16748 | 12578 | |
| <i>Arthrospira Jannetii</i> | | | | | | | | | | | | | | | | | | | |
| <i>Oscillatoria angustissima</i> | | | | | | | | | | | | | | | | | | | |
| <i>O. chlorina</i> | | | | | | | | | | | | | | | | | | | |
| <i>O. putida</i> | | | | | | | | | | | | | | | | | | | |
| <i>Spirulina Nordstedtii</i> | | | | | | | | | | | | | | | | | | | |
| Green algae | | | | | | | | | | | | | | | | | | | |
| <i>Actinostrom Nantzschii</i> | | | | | | | | | | 158 | | 420 | | | | | | | |
| <i>Ankistrodesmus convolutus</i> | | | | | | | | | | | | | | | | | | | |
| <i>A. falcatus</i> | 4673 | | 1470 | 315 | | | | | | | | | | | | | | | |
| <i>Chlorella ellipsoidea</i> | | | | | | | | | | | | | | | | | | | |
| <i>Coelastrum microporum</i> | | | | | | | | | | | | | | | | | | | |
| <i>Crucigenia rectangularis</i> | 189683 | | | | | | | | | 16328 | | | | | | | | | |
| <i>Oocystis Boryei</i> | | | | | | | | | | | | | | | | | | | |
| <i>Pediastrum duplex</i> | | | | | | | | | | | | | | | | | | | |
| <i>P. simplex</i> | | | | | | | | | | | | | | | | | | | 578 |
| <i>Scenedesmus carinatus</i> | | | | | | | | | | | | 1103 | | | | | | | |
| <i>S. dimorphus</i> | 3255 | | | | | | | | | | | | | | | | | | |
| <i>S. quadricauda</i> | 3728 | 3623 | | 683 | | | | 420 | | 1733 | | | | | | | | | 683 |
| <i>Synura uvella</i> | | | | | | | | | | | | | | | | | | | |
| <i>Ulothrix variabilis</i> | | | | | | | | | | | | | | | | | | | |
| <i>U. sonata</i> | | | | | | | | | | | | | | | | | | | |
| Diatoms | | | | | | | | | | | | | | | | | | | |
| <i>Caloneis amphibana</i> | | | | | | | 420 | | | | | | | | | | | | |
| <i>Cyclotella meneghiniana</i> | | | | | | | | | | | | | | | | | | | |
| <i>C. ocellata</i> | | | | | | | | | | | | | | | | | | | |
| <i>Cymatopleura solea</i> | | | | | | | | | | | | | | | | | | | |
| <i>Cymbella prostrata</i> | | | | | | | | | | | | | | | | | | | |
| <i>Fragilaria capucina</i> | | | | | | | | | | | | | | | | | | | |
| <i>Gomphonema olivaceum</i> | | | | | | | | | | | | | | | | | | | |
| <i>Gyrosigma sacrum</i> | | | | | | | | | | | | | | | | | | | |
| <i>G. wormsleyi</i> | | | | | | | | | | | | | | | | | | | |
| <i>Nantzschia amphioxys</i> | | | | | | | | | | | | | | | | | | | |
| <i>Melosira granulata</i> | | 1470 | | 683 | | 840 | 2153 | 210 | 3255 | | | | 210 | | 525 | | 315 | 2100 | |
| <i>Navicula canaliculata</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. cryptocephala</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. cuspidata</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. gastrum</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. graciloides</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. odiosa</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. radiosa</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. salinarum</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. sanoni</i> | | | | | | | | | | | | | | | | | | | |
| <i>Naidium dubium</i> | | | | | | | | | | | | | | | | | | | |
| <i>Nitzschia acicularis</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. angustata</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. signa</i> | | | | | | | | | | | | | | | | | | | |
| <i>N. tribionella</i> | | | | | | | | | | | | | | | | | | | |
| <i>Pinnularia caudata</i> | | | | | | | | | | | | | | | | | | | |
| <i>Surirella angustata</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. ovata</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. robusta</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. saxonica</i> | | | | | | | | | | | | | | | | | | | |
| <i>Synedra acuta</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. acuta</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. delicatissima</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. gena</i> | | | | | | | | | 158 | | | | | | | | | | |
| <i>S. fuscus</i> | | | | | | | | | | | | | | | | | | | |
| <i>S. ulna</i> | | | | | | | | | | | | | | | | | | | |
| Flagellates | | | | | | | | | | | | | | | | | | | |
| <i>Carteria multiceps</i> | | | | | | | | | | | | | | | | | | | |
| <i>Chlamydomonas reinhardi</i> | | | | | | | | | | | | | | | | | | | |
| <i>Euglena gracilis</i> | | | | | | | | | | | | | | | | | | | |
| <i>E. oxyuris</i> | | | | | | | | | | | | | 945 | | | | | | |
| <i>E. viridis</i> | 1523 | | | | | | | | | 158 | | | | | | | | | 315 |
| <i>Phacus pleuronectes</i> | | 578 | 263 | | | | | | | 525 | | | | | | | | | |
| <i>Trachelomonas oreban</i> | | | | | | | | | | | | | | | | | | | 138 |
| Dinoflagellates | | | | | | | | | | | | | | | | | | | |
| <i>Closterium sp.</i> | | | | | | | | | | | | | | | | | | | |
| <i>Coelastrum sp.</i> | | | | | | | | | | | | | | | | | | | |
| <i>Staurastrum cornutum</i> | | | | | | | | | | | | | | | | | | | |

Appendix D. Continued

| | November 16 | | | | | | | | November 30 | | | | | | | | | |
|----------------------------------|-------------|------|------|------|------|------|------|------|-------------|---|---|----|-----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 |
| Blue-green algae | | | | | | | | | | | | | | | | | | |
| <i>Anabaena flos-aquae</i> | | | | | | | | | | | | | | | | | | |
| <i>A. spiruloides</i> | | | | | | | | | | | | | | | | | | |
| <i>Anacyclus cyaneus</i> | | 473 | | | | | | | | | | | | | | | | |
| <i>A. thornelia</i> | | | | | | | | | | | | | | | | | | |
| <i>Aphanizomenon flos-aquae</i> | | | | | | 2153 | 840 | 1155 | | | | | 67 | | | 8 | 13 | |
| <i>Archrospira jennettii</i> | | | | | | | | | | | | | | | | | | |
| <i>Oscillatoria angustissima</i> | | | | | | | 998 | 6353 | 4252 | | | | 76 | | | 55 | 94 | 59 |
| <i>O. chlorina</i> | | | | | | | | | | | | | | | | | | |
| <i>O. putrida</i> | | | | | | | | | | | | | | | | | | |
| <i>Spirulina Nordstedtii</i> | | | | | | | | | | | | | | | | | | |
| Green algae | | | | | | | | | | | | | | | | | | |
| <i>Actinostromum Kantaschii</i> | 578 | | | | | | | | | | | | | 32 | | | | |
| <i>Ankistrodesmus convolutus</i> | | | | | | | | | | | | | | | | | | |
| <i>A. filiosus</i> | | | | | | | | | | | | | | | | | | |
| <i>Chlorella ellipsoidea</i> | | | | 2100 | | | | | | | | | | | | | | |
| <i>Chlorella microsporum</i> | | | | | | | | | | | | | | | | | | |
| <i>Crucigenia rectangularis</i> | 8873 | | | | | | | | | | | | | | | | | |
| <i>Oocystis Borgei</i> | | | | | | | | | | | | | | | | | | |
| <i>Pediastrum duplex</i> | | | | | | | | | | | | | | | | | | |
| <i>P. simplex</i> | | | | | | | | | | | | | | | | | | |
| <i>Scenedesmus carinatus</i> | | | | | | | | | | | | | | | | | | |
| <i>S. dimorphus</i> | 945 | 945 | 315 | 420 | 735 | | | 893 | 630 | | | | 44 | | | 42 | | |
| <i>S. quadricauda</i> | | | | | | | | | | | | | | | | | | |
| <i>Synura uvella</i> | | | | | | | | | | | | | | | | | | |
| <i>Synura variabilis</i> | | | | | | | | | | | | | | | | | | |
| <i>S. sonata</i> | | | 1523 | | 1050 | | 1995 | 683 | | | | | | 86 | | | | |
| Diatoms | | | | | | | | | | | | | | | | | | |
| <i>Cyclotella amphioxys</i> | | | | | | | | | | | | | | | | | | |
| <i>Cyclotella meneghiniana</i> | | | | | | | | | | | | | | | | | | |
| <i>C. ocellata</i> | | | | | | | | | | | | | | | | | | |
| <i>Cymatopleura solea</i> | 53 | | | | | | | | | | | | | | | | | |
| <i>Cymbella prostrata</i> | | | | | | | | | | | | | | | | | | |
| <i>Fenestrula capucina</i> | | | | | | | | | | | | | | | | | | |
| <i>Gomphonema olivaceum</i> | | | | | | | | | | | | | | | | | | |
| <i>Gyrodinium aureum</i> | | | | | | | | | | | | | | | | | | |
| <i>G. vernalis</i> | | | | | | | | | | | | | | | | | | |
| <i>Kantasia amphioxys</i> | | 53 | | | | | | | | | | | 17 | | | | | |
| <i>Mastogonia granulata</i> | | | | | 1050 | | | | 525 | | | | | | | | | |
| <i>Mastogonia canalis</i> | | | | | | | | | | | | | | | | | | |
| <i>M. erythrocephala</i> | | | | | | | | | | | | | | | | | | |
| <i>M. cuspidata</i> | | | | | | | | | | | | | | | | | | |
| <i>M. gastrum</i> | 840 | | | | | | | | | | | | | | | | | |
| <i>M. graciloides</i> | | | | | | | | | | | | | | | | | | |
| <i>M. odiosa</i> | | | | | | | | | | | | | | | | | | |
| <i>M. radiosa</i> | | | | | | | | | | | | | | | | | | |
| <i>M. salinarum</i> | | | | | | | | | | | | | | | | | | |
| <i>M. sonoi</i> | | | | | | | | | | | | | | | | | | |
| <i>Medium dubium</i> | | | | | | | | | | | | | | | | | | |
| <i>Nitzschia acicularis</i> | | | | | | | | | | | | | | | | | | |
| <i>N. angustata</i> | | | | | | | | | | | | | | | | | | |
| <i>N. sigma</i> | | | | | | | | | | | | | | | | | | |
| <i>N. tryblionella</i> | | | | | | | | | | | | | | | | | | |
| <i>Pinnularia caudata</i> | | | | | | | | | | | | | | | | | | |
| <i>Spirulina angustata</i> | | | | | | | | | | | | | | | | | | |
| <i>S. ovata</i> | | | | | | | | | | | | | | | | | | |
| <i>S. robusta</i> | | | | | | | | | | | | | | | | | | |
| <i>S. saxonica</i> | | | | | | | | | | | | | | | | | | |
| <i>Synedra acus</i> | 2153 | 1890 | | 4778 | | 4253 | | 1628 | 1208 | | | 34 | 166 | 6 | 95 | 34 | 8 | 27 |
| <i>S. acuta</i> | | | | | | | | | | | | | | | | | | |
| <i>S. delicatissima</i> | | 1103 | | | | | | | | | | | | | | | | |
| <i>S. nana</i> | | | | | | | | | | | | | | | | | | |
| <i>S. suspensa</i> | | | | | | | | | | | | | | | | | | |
| <i>S. ulna</i> | | | | | | | | | | | | | | | | | | |
| Flagellates | | | | | | | | | | | | | | | | | | |
| <i>Carteria multifida</i> | | | | | | | | | | | | | | | | | | |
| <i>Chlamydomonas reinhardtii</i> | | 268 | | | | | | | | | | | | | | | | |
| <i>Euglena gracilis</i> | 158 | | | | | | | | | | | | | | | | | |
| <i>E. oxyuris</i> | 683 | | | | | | | | | | | | | | | | | |
| <i>E. viridis</i> | | | | 683 | 315 | | | 893 | | | | | | | | | | 17 |
| <i>Phacus pleuronectus</i> | | | | | | | | | | | | | | | | | | |
| <i>Trachelomonas crebba</i> | | | | | | | | | | | | | | | | | | |
| Others | | | | | | | | | | | | | | | | | | |
| <i>Chlosterium</i> sp. | | | | | | | | | | | | | | | | | | |
| <i>Chlosterium</i> sp. | | | | | | | | | | | | | | | | | | |
| <i>Chlosterium cornutum</i> | | | | | | | | | | | | | | | | | | |

Appendix D. Continued

| | December 14 | | | | | | | | January 9 | | | | | | | |
|----------------------------------|-------------|----|----|----|----|----|----|----|-----------|-----|----|------|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Blue-green algae | | | | | | | | | | | | | | | | |
| <i>Anabaena flos-aquae</i> | | | | | | | | | | | | | | | | |
| <i>A. spiroides</i> | | | | | | | | | | | | | | | | |
| <i>Anacystis cyanea</i> | | | | | | | | | | | | | | | | |
| <i>A. thermalis</i> | | | | | | | | | | | | | | | | |
| <i>Aphanizomenon flos-aquae</i> | | | | | 55 | | | | | | | | | | | |
| <i>Archospira Jenneri</i> | | | | | | | | | | | | | | | | |
| <i>Oscillatoria angustissima</i> | 16 | | | | | 25 | 55 | 63 | | | | | | | 27 | 60 |
| <i>O. chlorina</i> | | | | | | | | | | | | | | | | |
| <i>O. putrida</i> | | | | | | | | | | | | | | | | |
| <i>Spirulina hustedtii</i> | | | | | | | | | | | | | | | | |
| Green algae | | | | | | | | | | | | | | | | |
| <i>Actinastrum Rantzschii</i> | 25 | | | | | | | | | | | | | | | |
| <i>Ankistrodasmus convolutus</i> | | | | | | | | | 44 | | | | | | | |
| <i>A. falcatum</i> | 17 | | | | | | | | | | | | | | | |
| <i>Chlorella ellipsoidea</i> | | | | | | | | | | 61 | | | | | | |
| <i>Coelastrum microporum</i> | | | | | | | | | | | | | | | | |
| <i>Crucigenia rectangularis</i> | | | | | | | | | 8 | | | | | | | |
| <i>Docyctis Borgei</i> | | | | | | | | | | | | | | | | |
| <i>Pediastrum duplex</i> | | | | | | | | | | | | | | | | |
| <i>P. simplex</i> | | | | | | | | | | 2 | | | | | | |
| <i>Scenedesmus coronatus</i> | 4 | | | | | | | | | | 25 | | | | | |
| <i>S. dimorphus</i> | | | | 53 | | | | | | | | | | | | |
| <i>S. quadricauda</i> | | | | | | | | | | | | | | | | |
| <i>Synura uvella</i> | | | | | | | | | | | | | | | 2 | |
| <i>Ulothrix variabilis</i> | | | | | | | | | | | | | | | | |
| <i>U. sonata</i> | | | | | 17 | 15 | | | | | | | 11 | | | |
| Diatoms | | | | | | | | | | | | | | | | |
| <i>Caloneis ephraeana</i> | | | | | | 8 | | | | | | | | | | |
| <i>Cyclotella meneghiniana</i> | | | | | | | | | | | | | | | | |
| <i>C. ocellata</i> | | | | | | | | | | | | | | | | |
| <i>Cymatopleura solea</i> | | | | | | | | | | | | | | | | |
| <i>Cymbella prostrata</i> | | | | | | | | | | | | | | | | |
| <i>Fragilaria capucina</i> | | | | | | | | | | | | | | | | |
| <i>Gomphonema olivaceum</i> | | | | | | | | | | | | | | | | |
| <i>Gyrodinium aureum</i> | | | | | | | | | | | | | | | | |
| <i>G. wormleyi</i> | | | | | | | | | | | | | | | | |
| <i>Rantzschia amphioxys</i> | | | | | | | | | | | | | | | | |
| <i>Melosira granulata</i> | | 4 | 19 | | | | | | | | | | | | | |
| <i>Navicula canalis</i> | | | | | | | | | | | | | | | | |
| <i>N. cryptocephala</i> | | | | | | | | | | | | | | | | |
| <i>N. cuspidata</i> | | | | | | | | | | | | | | | | |
| <i>N. gaehtum</i> | | | | | | | | | | | | | | | | |
| <i>N. graciloides</i> | | | | | | | | | | | | | | | | |
| <i>N. odiosa</i> | | | | | | | | | | | | | | | | |
| <i>N. radiosa</i> | | | | | | | | | | | | | | | | |
| <i>N. salinarum</i> | | | | | | | | | | | | | | | | |
| <i>N. sanonj</i> | | | | | | | | | | | | | | | | |
| <i>Naidium dubium</i> | | | | | | | | | | | | | | | | |
| <i>Nitzschia acicularis</i> | | | | | | | | | | | | | | 29 | | |
| <i>N. angustata</i> | | | | | | | | | | | | | | | | |
| <i>N. sigma</i> | | | | | | | | | | | | | | | | |
| <i>N. tryblionella</i> | | | | | | | | | | | | | | | | |
| <i>Pinnularia caudata</i> | | | | | | | | | | | | | | | | |
| <i>Surirella angustata</i> | | | | | | | | | | | | | | | | |
| <i>S. ovata</i> | | | | | | | | | | | | | | 4 | | 2 |
| <i>S. robusta</i> | | | | | | | | | | | | | | | | |
| <i>S. saxonica</i> | | | | | | | | | | | | | | | | |
| <i>Synedra acus</i> | 69 | 88 | 19 | 36 | 21 | | 13 | | 59 | 113 | 19 | 65 | 69 | 42 | 4 | |
| <i>S. acuta</i> | | | | | | | | | | | | | | | | |
| <i>S. delicatissima</i> | | | | | | | | | | | | | | | | |
| <i>S. nana</i> | | | | | | | | | | | | | | | | |
| <i>S. ruggens</i> | | | | | | | | | | | | | | | | |
| <i>S. ulna</i> | | | | | | | | | | | | | | | | |
| Flagellates | | | | | | | | | | | | | | | | |
| <i>Carteria multifilis</i> | | | | | | | | | | | | | | | | |
| <i>Chlamydomonas reinhardtii</i> | | | | | | | | | | | | | | | | |
| <i>Euglena gracilis</i> | | | | | | | | | | | | | | | | |
| <i>E. oxyuris</i> | | | | | | | | | | | | | | | | |
| <i>E. viridis</i> | 42 | | | | | | | | 37 | 42 | | 1012 | | | 6 | |
| <i>Phacus pleuronectus</i> | 11 | | | | | | | | | | | 4 | | | 2 | |
| <i>Trachelomonas crebba</i> | | | | | | | | | | | | | | | | |
| Others | | | | | | | | | | | | | | | | |
| <i>Closterium</i> sp. | | | | | | | | | | | | | | | | |
| <i>Coelastrum</i> sp. | | | | | | | | | | | | | | | | |
| <i>Staurastrum cornutum</i> | | | | | | | | | | | | | | | | |

Appendix D. Continued

| | 1 | 2 | 3 | 4 | 5a | 5b | 6 | 7 | 8 |
|-----------------------------------|----|----|---|---|----|----|----|---|-----|
| Blue-green algae | | | | | | | | | |
| <i>Anabaena flos-aquae</i> | | | | | | | | | |
| <i>A. spiroides</i> | | | | | | | | | |
| <i>Anacystis curvata</i> | | | | | | | | | |
| <i>A. thrausta</i> | | | | | | | | | |
| <i>Aphanizomenon flos-aquae</i> | | | | | | | | | |
| <i>Aphanizomenon flos-aquae</i> | | | | | | | | | |
| <i>Oscillatoria angustissima</i> | | | | | | | | | 22 |
| <i>O. chlorina</i> | | | | | | | | | |
| <i>O. putrida</i> | | | | | | | | | |
| <i>Spizulina Kordtskii</i> | | | | | | | | | |
| Green algae | | | | | | | | | |
| <i>Actinostrium Hantzschii</i> | | | | | | | | | |
| <i>Ankistrodesmus convolvulus</i> | | | | | | | | | |
| <i>A. falcatulus</i> | | | | | | | | | |
| <i>Chlorella ellipsoidea</i> | | 25 | | | | | | | |
| <i>Coccoloba microporum</i> | | | | | | | | | |
| <i>Crucigenia rectangularis</i> | | | | | | | | | |
| <i>Oocystis Borgei</i> | | | | | | | | | 5 |
| <i>Pediastrum duplex</i> | | | | | | | | | |
| <i>P. simplex</i> | | | | | | | | | |
| <i>Scenedesmus carinatus</i> | | | | | | | | | |
| <i>S. dimorphus</i> | | | | | | | | | |
| <i>S. quadricauda</i> | | | | | | | | | |
| <i>Synura uvella</i> | | | | | | | | | |
| <i>Ulothrix variabilis</i> | | | | | | | | | |
| <i>U. zonata</i> | | | | | | | | | |
| Diatoms | | | | | | | | | |
| <i>Caloneis amphibiaea</i> | | | | | | | | | |
| <i>Cyclotella meneghiniana</i> | | | | | | | | | |
| <i>C. ocellata</i> | | | | | | | | | |
| <i>Cymatopleura minor</i> | | | | | | | | | |
| <i>Cymbella prostrata</i> | | | | | | | | | |
| <i>Fragularia capucina</i> | | | | | | | | | |
| <i>Gomphonema olivaceum</i> | | | | | | | | | |
| <i>Gyrodinium aureum</i> | | 2 | | | | | | | |
| <i>G. vorleyi</i> | | | | | | | | | |
| <i>Hantzschia amphioxys</i> | | | | | | | | | |
| <i>Mastococys granulata</i> | | | | | | | | | |
| <i>Mastococys canalis</i> | | | | | | | | | |
| <i>M. crytocoephalis</i> | | | | | | | | | |
| <i>M. cuspidata</i> | | | | | | | | | |
| <i>M. gastrum</i> | | | | | | | | | |
| <i>M. graciloides</i> | | | | | | | | | |
| <i>M. odiosa</i> | | | | | | | | | |
| <i>M. radiosa</i> | | | | | | | | | |
| <i>M. solinarum</i> | | | | | | | | | |
| <i>M. zanonii</i> | | | | | | | | | |
| <i>Reidius dubius</i> | | | | | | | | | |
| <i>Witzschia acicularis</i> | | | | | | 11 | | | |
| <i>W. angustata</i> | | | | | | | | | |
| <i>W. sigma</i> | | | | | | | | | |
| <i>W. tryblionella</i> | | | | | | | | | |
| <i>Pinnularia caudata</i> | | | | | | | | | |
| <i>Sarothamnia angustata</i> | | | | | | | | | |
| <i>S. ovata</i> | | | | | | | | | |
| <i>S. robusta</i> | | | | | | | | | 3 |
| <i>S. saxonica</i> | | | | | | | | | |
| <i>S. acuta</i> | 59 | 8 | | | 44 | 44 | 27 | | 1 |
| <i>S. acuta</i> | | | | | | | | | |
| <i>S. delicatissima</i> | | | | | | | | | |
| <i>S. nana</i> | | | | | | | | | |
| <i>S. rumpona</i> | | | | | | | | | |
| <i>S. vana</i> | | | | | | | | | |
| Flagellates | | | | | | | | | |
| <i>Catella multifida</i> | | | | | | | | | |
| <i>Chlamydomonas reinhardi</i> | | | | | | | | | 229 |
| <i>Euglena gracilis</i> | | | | | | | | | |
| <i>E. oxyuris</i> | | | | | | | | | |
| <i>E. viridis</i> | 21 | | | | 57 | | 11 | | 4 |
| <i>Phacus pleuronectus</i> | | | | | | | | | 11 |
| <i>Trachelomonas ovata</i> | | | | | | | | | |
| Others | | | | | | | | | |
| <i>Closterium</i> sp. | | | | | | | | | |
| <i>Coccoloba</i> sp. | | | | | | | | | |
| <i>Staurastrum cornutum</i> | | | | | | | | | |

Appendix E-1. Benthic Macroinvertebrates in Horseshoe Lake
(Number of individuals per square meter)

| May 24-25 | | | | | | | | |
|-------------------|---------|------|-----|------|------|------|------|------|
| | Station | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Chironomidae | 2526 | 388 | | 258 | 86 | 818 | 330 | 1335 |
| <i>Chaoborus</i> | | 789 | 101 | | 962 | 201 | 703 | 129 |
| Ceratopogonidae | | 14 | 14 | | | | | |
| Oligochaeta | 976 | 330 | 345 | 1120 | 43 | 517 | 804 | 1407 |
| Total individuals | 3502 | 1521 | 460 | 1378 | 1091 | 1536 | 1837 | 2871 |

| June 21-22 | | | | | | | | |
|-------------------|---------|------|-----|------|-----|------|------|------|
| | Station | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Chironomidae | 689 | 660 | 43 | 373 | | 1392 | 1120 | 890 |
| <i>Chaoborus</i> | | 345 | 14 | 43 | 273 | 14 | 144 | 57 |
| Ceratopogonidae | 14 | 14 | | | | | | |
| Oligochaeta | 703 | 86 | 316 | 1048 | 86 | 545 | 445 | 1163 |
| Total individuals | 1406 | 1105 | 373 | 1464 | 359 | 1951 | 1709 | 2110 |

| July 18-19 | | | | | | | | |
|-------------------|---------|-----|----|-----|-----|-----|-----|-----|
| | Station | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Chironomidae | 301 | 345 | | 57 | | 244 | 502 | 230 |
| <i>Chaoborus</i> | | 359 | 14 | 29 | 273 | 57 | 72 | 43 |
| Oligochaeta | 273 | 101 | | 201 | 14 | 144 | 359 | 388 |
| Total individuals | 574 | 805 | 14 | 287 | 287 | 445 | 933 | 661 |

| August 15-16 | | | | | | | | |
|-------------------|---------|------|-----|-----|-----|-----|-----|-----|
| | Station | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Chironomidae | 172 | 603 | 330 | 100 | 14 | 258 | 287 | 488 |
| <i>Chaoborus</i> | | 761 | 29 | 14 | 617 | 14 | 201 | 287 |
| Ceratopogonidae | | | | | | | | |
| Oligochaeta | 172 | 29 | 43 | 78 | | 100 | 43 | 57 |
| Hirudinea | 14 | | | | | | | |
| Total individuals | 358 | 1393 | 402 | 192 | 631 | 372 | 531 | 832 |

| September 13-14 | | | | | | | | |
|-------------------|---------|------|-----|-----|-----|-----|-----|-----|
| | Station | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Chironomidae | 1177 | 359 | 115 | 215 | | 689 | 287 | 359 |
| <i>Chaoborus</i> | 29 | 1665 | 43 | 244 | 574 | 187 | 215 | 159 |
| Ceratopogonidae | | | | | | | | |
| Oligochaeta | 57 | 14 | 14 | 29 | 43 | 100 | 29 | 129 |
| Hirudinea | 129 | | | | | | | |
| Total individuals | 1392 | 2038 | 172 | 488 | 617 | 976 | 531 | 647 |

Appendix. E-1. Concluded

October 11-12

| | Station | | | | | | | |
|--------------------------|-------------|-------------|------------|------------|-------------|------------|------------|------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Chironomidae | 334 | 258 | 115 | 57 | 14 | 115 | 345 | 474 |
| <i>Chaoborus</i> | | 832 | 359 | 29 | 1234 | 78 | 316 | 258 |
| Ceratopogonidae | 732 | | | | | | | |
| Oligochaeta | 57 | 14 | 29 | 43 | 57 | 100 | 57 | 129 |
| Hirudinea | 14 | | | | | | | |
| <i>Platnemis</i> | 14 | | | | | | | |
| Total individuals | 1151 | 1004 | 503 | 129 | 1305 | 293 | 718 | 861 |

November 15-16

| | Station | | | | | | | |
|--------------------------|------------|-------------|------------|------------|-------------|------------|------------|-------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Chironomidae | 115 | 144 | 215 | 215 | 43 | 388 | 388 | 474 |
| <i>Chaoborus</i> | | 1220 | 43 | 172 | 1923 | 215 | 287 | 330 |
| Oligochaeta | 86 | 29 | 14 | 72 | | 100 | 215 | 301 |
| Total individuals | 201 | 1393 | 273 | 459 | 1966 | 703 | 890 | 1105 |

December 13-14

| | Station | | | | | | | |
|--------------------------|-----------|-------------|-----------|------------|------------|------------|------------|------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Chironomidae | 14 | 316 | NS | 172 | 14 | 301 | 388 | 172 |
| <i>Chaoborus</i> | 14 | 875 | NS | 72 | 861 | 129 | 201 | 172 |
| Oligochaeta | 43 | 115 | NS | 100 | 43 | 187 | 100 | 115 |
| Hirudinea | 14 | | NS | | | | | |
| Total individuals | 85 | 1306 | NS | 344 | 918 | 617 | 689 | 459 |

Note: NS = no sample

January 22-23

| | Station | | | | | | | |
|--------------------------|------------|------------|------------|------------|------------|------------|------------|-------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Chironomidae | 43 | 301 | 574 | 115 | 72 | 344 | 402 | 1722 |
| <i>Chaoborus</i> | | 646 | 143 | 258 | 890 | 209 | 158 | 158 |
| Oligochaeta | 344 | 14 | 100 | 187 | 29 | 215 | 100 | 230 |
| Total individuals | 387 | 961 | 817 | 560 | 991 | 768 | 660 | 2110 |

Appendix E-2. Non-Quantitative Macroinvertebrate Samples Collected with an Aquatic Dip Net at Horseshoe Lake, August 3, 1978

| | Station | | | | | | | |
|--------------------------------|---------|-----|----|-----|----|------|-----|-----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Diptera | | | | | | | | |
| Ceratopogonidae | | | | | | | 1 | |
| Chironomidae | 20 | | | | 1 | | 2 | 111 |
| Hemiptera | | | | | | | | |
| Corixidae | | | | | | | | |
| <i>Corixella edulis</i> | 20 | 1 | | | | | | |
| <i>Ramphocorixa accuminata</i> | 7 | | | | | | | |
| <i>Trichocorixa kanza</i> | 2328 | 152 | 42 | 853 | 72 | 3598 | 656 | 675 |
| Notonectidae | | | | | | | | |
| <i>Buena margaritacea</i> | 9 | | | | | | | |
| Coleoptera | | | | | | | | |
| <i>Dineutus</i> | | | | | | 14 | | |
| Hirudinea | | | | | | | | |
| | 1 | | | | | | | |
| Gastropoda | | | | | | | | |
| <i>Physa</i> | 1 | | | 1 | | 3 | 10 | |
| <i>Lymnaea</i> | | 34 | | 9 | | 1 | 2 | 14 |

Appendix F. Concluded

| | November 16 | | | | November 30 | | | | December 14 | | | | January 9 | | | |
|---------------------------------|-------------|----|-----|------|-------------|----|----|-----|-------------|----|-----|-----|-----------|-----|-----|-----|
| | Station | | | | Station | | | | Station | | | | Station | | | |
| | 2 | 3 | 5 | 7 | 2 | 3 | 5 | 7 | 2 | 3 | 5 | 7 | 2 | 3 | 5 | 7 |
| <i>Asplanchna priodonta</i> | | | | | | | | | | | | | | | | |
| <i>Asplanchnopus myrmeleo</i> | | | | | | | | | | | | | | | | |
| <i>Bosmina longirostris</i> | 100 | 50 | | | | | | | | | | | | | | |
| <i>Bosmina obtusirostris</i> | | | | | | | | | | | | | | | | |
| <i>Brachionus calyciflorus</i> | | | | | | | | | | | | | | | | |
| <i>Brachionus havanaensis</i> | | | | | | | | | | | | | | | | |
| <i>Brachionus variabilis</i> | | | | | | | | | | | | | | | | |
| <i>Cyclops strenuus</i> | | | | | | | | | | | | 100 | | | | |
| <i>Cyclops vernalis</i> | | | | | | | | | | | | | | | | |
| <i>Daphnia pulex</i> | | | | | | 50 | | | | | | | | | | |
| <i>Diaptomus pallidus</i> | 50 | | 600 | 1000 | 225 | 50 | 25 | 200 | | | 125 | 300 | | 125 | 100 | 675 |
| <i>Diaptomus reighardi</i> | | | | | | | | | | | | | | | 25 | |
| <i>Keratella cochlearis</i> | | | | | | | | | | | | | | | | |
| <i>Keratella valga</i> | | | | | | | | | | | | | | | | |
| <i>Kurzia latissima</i> | | | | | | | | | | | | | | | | |
| <i>Limnocalanus macrurus</i> | | | | | | | | | | | | | | | | |
| <i>Mesocyclops edax</i> | | | | | | | | | | | | | | | | |
| <i>Osphranticum labronectum</i> | | | | | | | | | | | | | | | | |
| <i>Parastenocaris starretti</i> | | | | | | | | | | | | | | | | |
| Total individuals | 150 | 50 | 600 | 1000 | 275 | 50 | 25 | 200 | 0 | NA | 125 | 400 | 0 | 125 | 125 | 675 |

| | January 23 | | | |
|---------------------------------|------------|---|---|-----|
| | Station | | | |
| | 2 | 3 | 5 | 7 |
| <i>Asplanchna priodonta</i> | | | | |
| <i>Asplanchnopus myrmeleo</i> | | | | |
| <i>Bosmina longirostris</i> | 25 | | | |
| <i>Bosmina obtusirostris</i> | | | | |
| <i>Brachionus calyciflorus</i> | | | | |
| <i>Brachionus havanaensis</i> | | | | 350 |
| <i>Brachionus variabilis</i> | | | | |
| <i>Cyclops strenuus</i> | | | | |
| <i>Cyclops vernalis</i> | | | | |
| <i>Daphnia pulex</i> | | | | |
| <i>Diaptomus pallidus</i> | | | | 525 |
| <i>Diaptomus reighardi</i> | | | | |
| <i>Keratella cochlearis</i> | | | | |
| <i>Keratella valga</i> | | | | |
| <i>Kurzia latissima</i> | | | | |
| <i>Limnocalanus macrurus</i> | | | | |
| <i>Mesocyclops edax</i> | | | | |
| <i>Osphranticum labronectum</i> | | | | |
| <i>Parastenocaris starretti</i> | | | | |
| Total individuals | 25 | 0 | 0 | 875 |