Illinois State Water Survey Division

WATER QUALITY SECTION

AT

PEORIA, ILLINOIS

SWS Contract Report 407

WATER QUALITY MONITORING OF JOHNSON SAUK TRAIL LAKE AFTER IMPLEMENTATION OF MANAGEMENT TECHNIQUES

by

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Prepared for the
Illinois Department of Conservation
Illinois Environmental Protection Agency
U.S. Environmental Protection Agency

November 1986

Illinois Department of Energy and Natural Resources

CONTENTS

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INTRODUCTION

Johnson Sauk Trail Lake, located in Henry County, Illinois, is a 57.4-acre (23.2-ha) lake with maximum and mean depths of 23.0 feet C7.0I m) and 8.2 feet (2.50 m), respectively. The lake was formed in 1956 by the impoundment of King Creek. The lake and the surrounding Johnson Sauk Trail State Park are managed by the Illinois Department of Conservation (IDOC) for outdoor recreational activities. These activities include bank, boat, and ice fishing; boating and canoeing; camping; picnicking; hunting; horseback riding; and various other summer and winter outdoor recreational activities. The location of the lake, and the locations of its public access points and facilities, are shown in figure 1. Other relevant information is given in table 1.

The lake's watershed encompasses a total area of 876.1 acres (354.6 ha) and is in excellent condition. Over 86% of the watershed is in permanent vegetative cover with little or no land disturbance. Predominant land uses in the watershed are grassland (46.4%), woodland (40.2%), and recreational development (6.9%); the rest is water.

A detailed limnological study of Johnson Sauk Trail Lake was conducted during 1981 with funding from The U.S. Environmental Protection Agency (USEPA) and IDOC under provisions of the Clean Lakes Program authorized by Section 314 of The Clean Water Act. The study (Kothandaraman and Evans, 1983) indicated that the lake remains highly eutrophic, even though the watershed has long been returned to a relatively undisturbed condition. The lake water quality characteristics were found to be typical of Illinois lakes, with high alkalinity, conductivity, and dissolved solids concentrations. There was an abundance of phosphorus in the lake system at all times. Lake tributaries were not found to convey unusual amounts of suspended sediment or nutrient loads. The lake received sediments from its watershed at the annual rate of 3.3 tons/acre. Internal regeneration of nitrogen and phosphorus under anoxic conditions during summer thermal stratification accounted for 93.5% of the inorganic nitrogen loading and 75% of the dissolved phosphorus loading to the lake. Tributaries contributed only 1.5 and 17.7% of inorganic nitrogen and

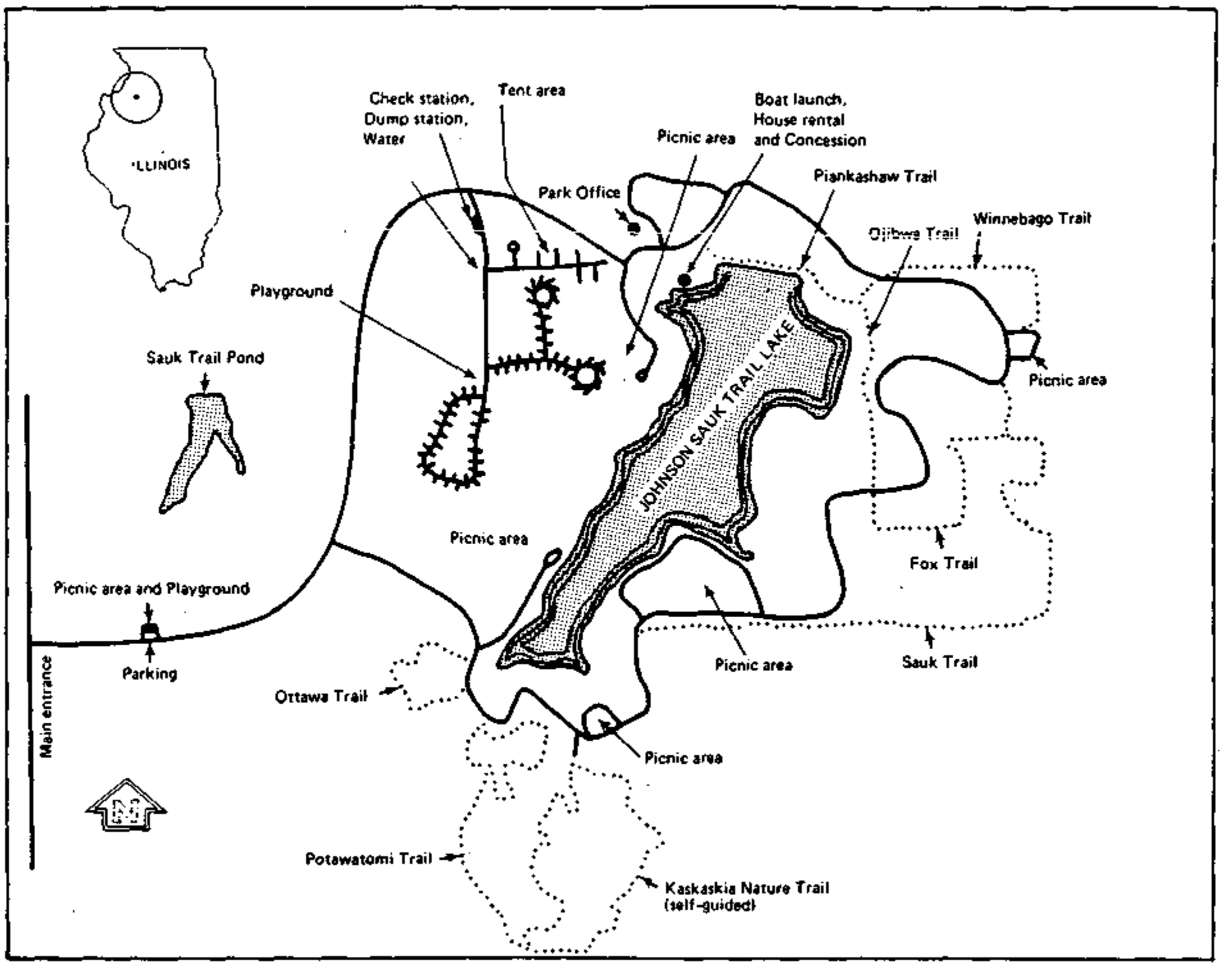

Figure 1. Public access points and facilities, Johnson Sauk Trail Lake

Table 1. Morphometric Details Pertaining to Johnson Sauk Trail Lake

Surface area, acres	57.4 (23.2 ha)
Volume, acre-feet	471.5 (0.58 x $10^6 m^3$)
Mean depth, feet	8.2 (2.50 m)
Maximum depth, feet	23.0 (7.01 m)
Length of shoreline, miles	1.5 (2.41 km)
Average retention time, years	1.96
Watershed area, acres	876.1 (3.55 km^2)

dissolved phosphorus, respectively; the remainder emanated from atmospheric precipitation and dry fallout Cibid).

The detailed limnological data developed for the lake (Kothandaraman and Evans, 1983) identified the lake's major water quality problems as:

- Oxygen depletion at depths below 8 feet from the water surface during the summer stratification period.
- Algal growths of bloom proportions in the lake, with blue-green algae as the dominant species.
- Extensive growth of macrophytes covering about 27% of the lake surface and interfering with recreational activities.

On the basis of technical, environmental, and economic considerations, the following in-lake management techniques were chosen for implementation:

- Aeration/destratification of the lake.
- Periodic applications of chelated copper sulfate followed by potassium permanganate applications.
- Harvesting of macrophytes from selected areas in the lake.
- Lake shore stabilization at two on-shore locations totalling 300 feet in length.

Desirable water quality goals established for Johnson Sauk Trail Lake were: dissolved oxygen concentrations of at least 5.0 mg/L throughout the lake, secchi disc transparency of not less than 4 feet during summer months, total phosphorus of less than 0.05 mg/L at the time of spring turnover, average annual suspended solids less than 25 mg/L, and turbidity values of less than 25 units. The primary objectives of the lake management program were:

- Improve fish habitat in the lake during summer and winter months by eliminating anoxic conditions in the lake.
- Minimize internal regeneration of nutrients in the lake.
- Improve the aesthetic quality of the lake waters and enhance recreational opportunities in the lake.
- Control algal blooms and dense macrophyte growth in the lake which occur during the prime recreational period.
- Enhance bank fishing in addition to open water fishing.

Implementation and monitoring of the in-lake water quality management techniques were partially funded by USEPA through a Clean Lakes Program Phase II grant (project period July 1, 1983 - June 30, 1986). Nonfederal match was provided by IDOC and the Illinois State Water Survey (ISWS) (see project budget, appendix 4). IDOC provided additional funding for monitoring the lake from May to September 1985. Project administration was provided by the Illinois Environmental Protection Agency (IEPA). The Water Quality Section of the Illinois State Watar Survey monitored the lake's water quality during and after implementation of the water quality management scheme. This report presents the data and results related to the in-lake water quality management techniques in Johnson Sauk Trail Lake and serves as the final Phase II project report to USEPA.

Acknowledoments

This investigation, partially funded by the Illinois Department of Conservation and U.S. Environmental Protection Agency through the Illinois Environmental Protection Agency, was conducted under the general administrative guidance of Richard J. Schicht, Acting Chief of the Illinois State Water Survey.

Several Water Survey staff members contributed to this investigation. Dana Shackleford and Billy Cook performed chemical analyses; illustrations were prepared under the supervision of John W. Brother, Jr.; Gail Taylor edited the manuscript; and Linda Johnson typed the initial and final reports.

The excellent cooperation, assistance, and courtesy extended by Jerry McClure and his staff -- particularly Edward Saey -- of Johnson Sauk Trail State Park (IDOC) are appreciated. Alec Pulley, IDOC fisheries biologist, applied algicides to the lake as needed and provided fish survey data. Don Dillenburg, IDOC regional engineer, arranged the purchase and installation of the destratifier for the lake and was very helpful in the overall project management. The assistance of Donna Sefton, IEPA lakes program manager, in the successful completion of the project is appreciated very much.

MATERIALS AND METHODS

An axial flow, low-energy, mechanical pump similar to that developed by Quintero and Gar ton (1973) at Oklahoma State University, Stillwater, OK, was used to destratify Johnson Sauk Trail Lake. The destratifier consists of an 8-foot-diameter propeller with six variable pitch symmetrical blades mounted on a vertical shaft (29.5 RPM), driven by a 2-horsepower (220 V, single phase, 1740 RPM) motor through a system of gear reduction box and pulley-belt arrangements. The system is mounted on a floating platform such that the propeller is located about 5 feet below the water surface. The pitch of the individual blade can be set at any desired angle within the range of 14 to 30 degrees. As the blades are symmetrical, the pumping efficiency will remain the same whether lake water is pumped from the surface toward the bottom or vice versa. A reversible switch in the system permits the direction of rotation of the motor and consequently the direction of rotation of the propeller to be reversed with ease.

The destratifier was installed on July 2, 1984, and began operating the next day. However, it remained inoperative most of the time until August 24, 1984, because of improper initial pulley size selection, inadequate fastening arrangement of the propeller to the vertical shaft, and a few other minor deficiencies in the design and fabrication of the system. The unit was hauled ashore and repaired and was then reinstalled on August 24, 1984, after which it operated well without any mechanical failure. The unit was purchased and installed at a total cost of $9,247. (See project budget, appendix 4.)

The destratifier was operated in the downflow mode during summer stratification and in the upflow mode during the winter months to bring the warmer near-bottom waters to the surface to keep a portion of the lake from freezing up. The system was operated continuously from August 24, 1984, until March 13, 1985, when it was shut off because of the natural spring overturn.

The destratifier's motor was found inoperative on April 16, 1985, during a routine monitoring trip to the lake. The old motor was replaced with a new 3-horsepower (230 V, single phase, 1740 RPM) motor and the system was restarted on May 2, 1985. The system then operated continuously until the end of the monitoring period except from June 8 to June 11, 1985, when it remained shut down due to power failure. Figure 2 shows the destratifier before and after its installation in the lake. The power cost for operating the destratifier continuously was estimated as $90 per month. The maintenance (motor replacement) cost was S486.

Copper sulfate was applied to the lake at the rate of 5.4 lbs/acre once during 1984 (on August 8) and once during 1985 (on June 28). On each occasion, citric acid was used as a chelating agent in the weight ratio of two copper sulfate pentahydrate to one citric acid monohydrate. For each application, 310 pounds of copper sulfate and 155 pounds of citric acid were used. The chemicals were placed in porous burlap bags and tied to the destratifier raft with the destratifier operated in the upflow mode during the period of chemical application. The flow induced by the destratifier past the bags dissolved and dispersed the chemicals. This method of chemical application required very

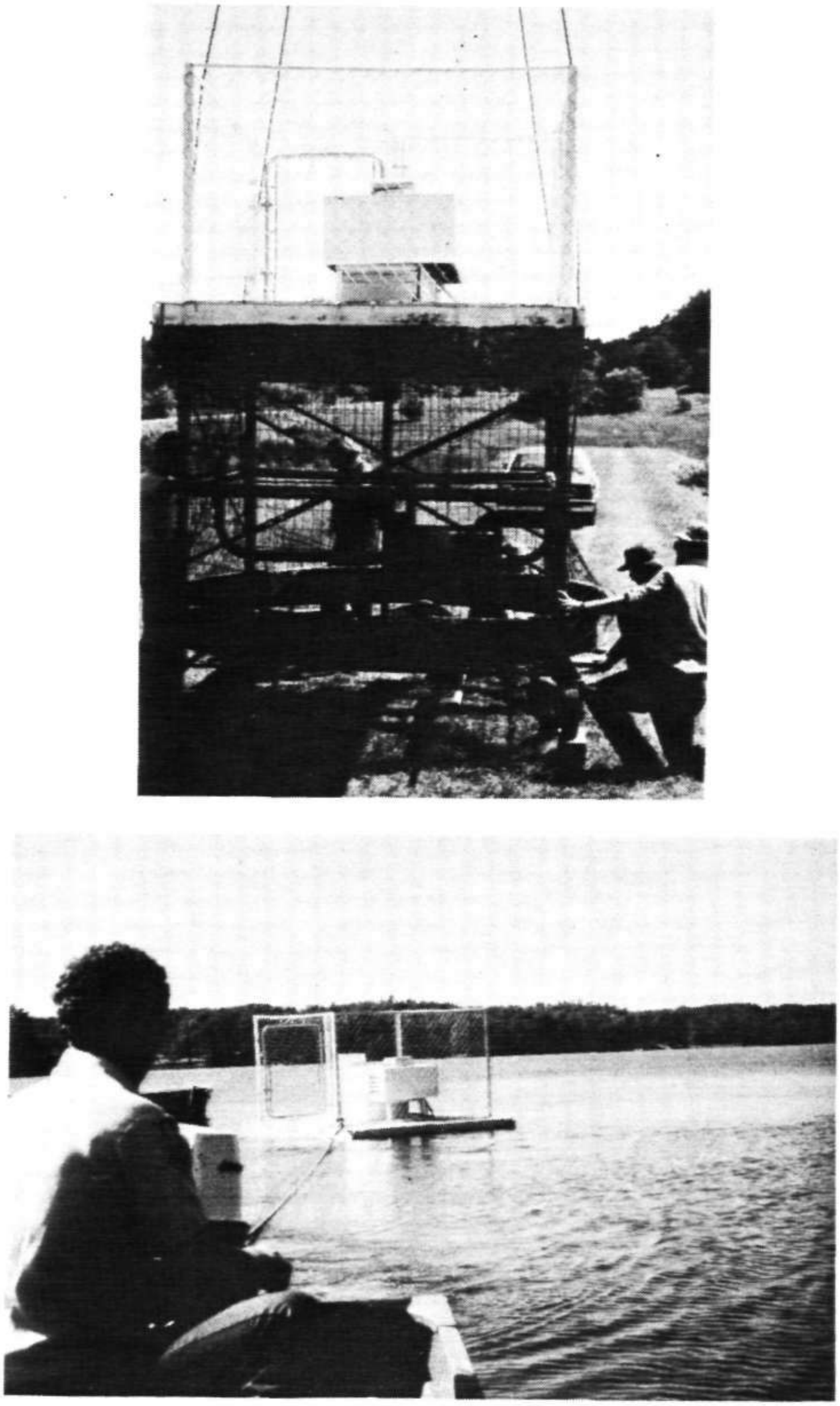

Figure 2. Views of the destratifier before and after installation

minimal labor. Samples for copper analyses were obtained at the surface and at 2 feet below the surface at stations 1, 2, and 3 (figure 3) from 24 to 48 hours after the initial application of the algicide. Algicide treatment was followed after 24 to 48 hours by a treatment of 60 pounds of potassium permanganate. Potassium permanganate was used primarily to oxidize the decaying algal cells wh.ich otherwise would exert an undue demand on the oxygen resources of the lake water. Potassium permanganate was applied in a similar manner to the copper sulfate application.

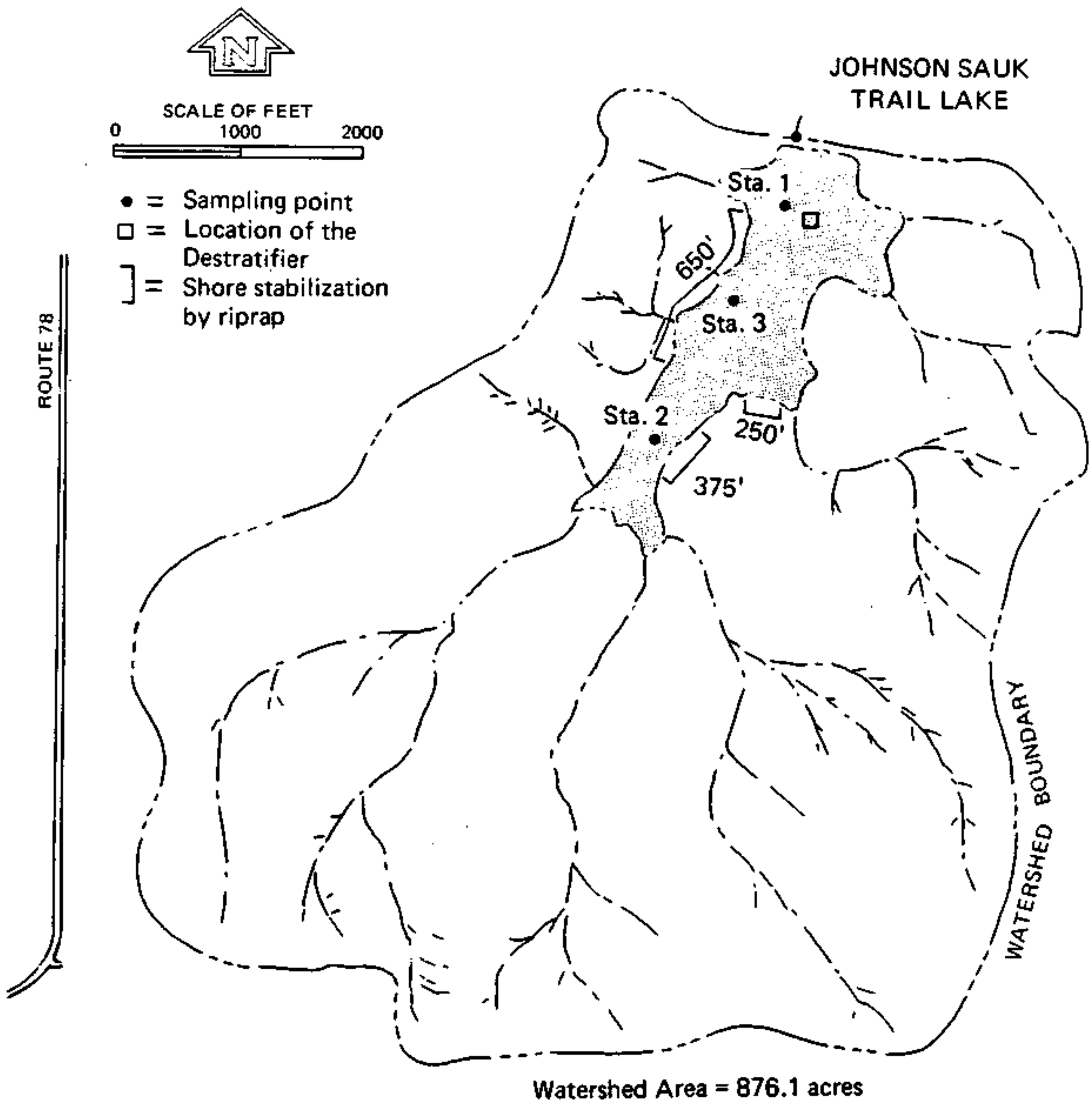

Figure S. Locations of sampling points, shoreline stabilization sites, and destratifier in Johnson Sauk Trail Lake

Macrophytes were harvested and removed from the lake with a 4-foot-cut mechanical harvester during the period June 11 to June 17, 1984. The harvested macrophytes were manually removed from the harvester to a front-end loader, loaded into a dump truck, and transported and disposed of on land within the park boundaries. The harvesting was accomplished at a contracted cost of $4800 for 80 machine hours. The cost of manpower involved in offsite disposal of the harvested weeds was $1292 C160 man-hours of maintenance workers at $3.50/hr and 60 man-hours of park supervising staff at S12.20/hr). A front-end loader and dump truck were used for 40 hours each at a total cost of $2000. Approximately 10 of the 15.4 acres of macrophyte beds were harvested, leaving a 9% coverage. A total of 172 tons (wet weight) of macrophytes were harvested. This was estimated to have resulted in an export of 125 pounds of total phosphorus from the lake.

Macrophytes were again harvested during the period June 5 to June 9, 1985, with three different sizes of weed harvesters. The capacities of the weed harvesters used in 1985 were: 6-foot cut, 225 cubic feet (cft), and 4 hour/acre; 5-foot cut, 150 cft, and 5 hour/acre; and 4-foot cut, 100 cft, and 6 hour/acre. A total of 80 machine hours were needed to harvest the lake at a contracted cost of $5200. State park personnel were used to transfer the harvested vegetation from the harvesters onto the bucket of a front-end loader and then onto a dump truck for final land disposal. Eighty-eight man-hours of regular park personnel and 80 man-hours of temporary summer employees were used in transferring the harvested vegetation to a dump truck and transporting it for final disposal. The estimated manpower cost was $1200 ($10/hr for park personnel and $4/hr for temporary help). The cost of operating the end loader and dump truck amounted to $2,000 at $25/hr for a total of 40 hours each. Harvesting results obtained for 1985 were similar to those for 1984.

Shoreline stabilization to prevent soil erosion was completed in 1984 through the use of riprap. A total of 350 tons of riprap purchased at a cost of $5058 were placed along three major segments of the lake (the critical areas originally identified, as well as additional areas), as shown in figure 3. An end loader and a back hoe were used for 27-1/2 hours to place and dress the riprap. Cost of this operation was $1,065.

To assess the efficacy of the in-lake water quality management scheme in improving lake water quality, certain physical, chemical, and biological measurements were made. The locations of the destratifier, shoreline stabilization, and the sampling stations in the lake are shown in figure 3. Stations 1 and 2 were monitored routinely and station 3 was used only in sample collections for copper analyses.

Physical and chemical water quality characteristics were evaluated at biweekly intervals from May to September of both 1984 and 1985 and at monthly intervals during the remainder of the project period. Phytoplankton and chlorophyll were monitored at biweekly intervals from May to September, and benthos were examined once a month from June to September.

In-situ observations for temperature, dissolved oxygen, and secchi disc readings were made at the deep and shallow stations (stations 1 and 2, respectively) in the lake. An oxygen meter. Yellow Spring Instrument Company model 54 with a 50-foot probe, was standardized in lake surface water in which dissolved oxygen content was determined by the modified Winkler method as outlined by the American Public Health Association et al. (1980). Temperature and dissolved oxygen measurements were obtained in the water column at 2-foot intervals for the deep station and at 1-foot intervals for the shallow station, commencing from the surface of the lake.

For measuring secchi disc transparencies, an 8-inch-diameter secchi disc with black and white quadrant markings attached to a calibrated line was used. The disc was lowered until it disappeared from view, and the depth of immersion of the disc was noted. The disc was lowered farther and then raised slowly until it reappeared. Again the depth of immersion was noted. The average of these two observations was recorded as the secchi disc readings.

Water samples for chemical analyses were obtained from station 1 with a Kemmerer sampler 1 foot below the surface, at mid-depth, and 1 foot from the bottom. Integrated water samples within a depth twice the secchi disc readings were also obtained at station 1 for phytoplankton identification and enumeration and for chlorophyll-a determination. A Juday sampler was used for obtaining integrated samples.

All the samples were stored on ice during transportation and kept in a refrigerator until processed, with the exception of the algae and chlorophyll-a samples. Chlorophyll-a samples were kept frozen. Water subsamples in a volume of 380 ml were collected for algal identification and enumeration, preserved with 20 mL of formalin at the time of collection, and stored at room temperature until examined.

Determinations for pH, alkalinity, and conductivity were made at the lake site soon after sample collections. Laboratory analyses were performed to determine total suspended and dissolved solids, volatile suspended solids, turbidity, total and dissolved phosphorus, nitrate-nitrogen, total ammonia-nitrogen and Kjeldahl-nitrogen, and chlorophyll-a. The methods and procedures involved in these determinations are given in table 2.

Table 2. Analytical Procedures

Turbidity	Nephelometric method, using Turner Fluorometer, model 110; Formazin used as a standard
pH	Glass electrode method with portable Metrohm-Herisau meter (model E588)
Total solids	Residue on evaporation overnight on a steam bath at 103-105°C
Suspended solids	Dry weight of solids retained on gooch crucible with fiberglass filter
Suspended volatile solids	Loss on ignition of suspended solids at 550°C in a muffle furnace for 1 hour
Alkalinity	Potentiometric method; titration with standard sulfuric acid solution to an end point pH of 4.3
Conductivity	YS1 model 33 conductivity meter
Total phosphorus	Sample was digested with sulfuric-nitrate acid mixture and determined by ascorbic acid method
Total dissolved phosphorus	Sample was first filtered through 0.45 um filter paper, digested with sulfuric acid mixture, and determined by ascorbic acid method
Ammonia-N	Phenate method
Nitrate-N	Chromotropic method
Kjeldahl-N	Digestion and distillation followed by endophenol-hypochlorite colorimetric determination
Chlorophyll-a	Sample was filtered through 0.45 μm filter paper, the pigment extracted with 90% acetone (v/v), and the concentration determined spectrophotometrically at 665 nu correcting for absorbance at 750, 645, and 630 nm (Jones and Lee, JAWVA, Vol. 74, No. 9, pp. 490-494).

For algal identification and enumeration, the sample was thoroughly mixed and a 1-ml aliquot was pipetted into a Sedgwick Rafter Cell. A differential interference contrast microscope equipped with a 10X or 20X eyepiece, 20X or 100X objective, and a Whipple disc was used for identification and counting purposes. Five short strips were counted. The algae were identified as to species and were classified into five main groups: blue-greens, greens, diatoms, flagellates, and others. For enumeration, blue-green algae were counted by trichomes. Green algae were counted by individual cells except for Actinastrum, Coelastrum, and Pediastrum. which were recorded by each colony observed. Scenedesmus was counted by each cell packet. Diatoms were counted as one organism regardless of their grouping connections. For flagellates, a colony of Dinobrvon or a single cell of Ceratiurn was recorded as a unit. The dimensions of individual organisms reported earlier (Kothandaraman and Evans, 1983) were used for computing biovolumes of the algal mass in the samples.

Benthic samples for macroinvertebrate examination were obtained at monthly intervals during June through September. Benthic samples were obtained at both the deep and shallow stations (stations 1 and 2). Three grabs with an Ekman dredge (6 x 6 inches) were taken at each station for macroinvertebrate analyses. The samples were washed in a 30-mesh screen bucket and the residue was placed in quart jars and preserved in 95% ethyl alcohol. In the laboratory, the samples were washed again and the organisms were picked from the bottom detritus. They were identified to genus level, counted, and preserved in 70% ethyl alcohol .

RESULTS AND DISCUSSION

Phvsical Characteristics

Temperature. The thermal stratification of deep lakes, impoundments, and reservoirs in the temperate zone is a natural phenomenon. Even very shallow lakes (5 to 10 feet) under certain conditions are known to exhibit thermal gradients of 6 C in 5 feet of water (Hill et al., 1981; Kothandaraman et al., 1977). Most of the physical, chemical, and biological characteristics of impounded waters are functions of temperature. Closely related to temperature variation in lake water is the physical phenomenon of increasing density with decreasing temperature up to a certain point. Together, these two interrelated forces are capable of creating strata of water of vastly differing characteristics. Johnson Sauk Trail Lake is no exception to this phenomenon.

Kothandaraman and Evans (1983) reported that during 1981 summer stratification in Johnson Sauk Trail Lake began to set in during the latter half of May and intensified progressively

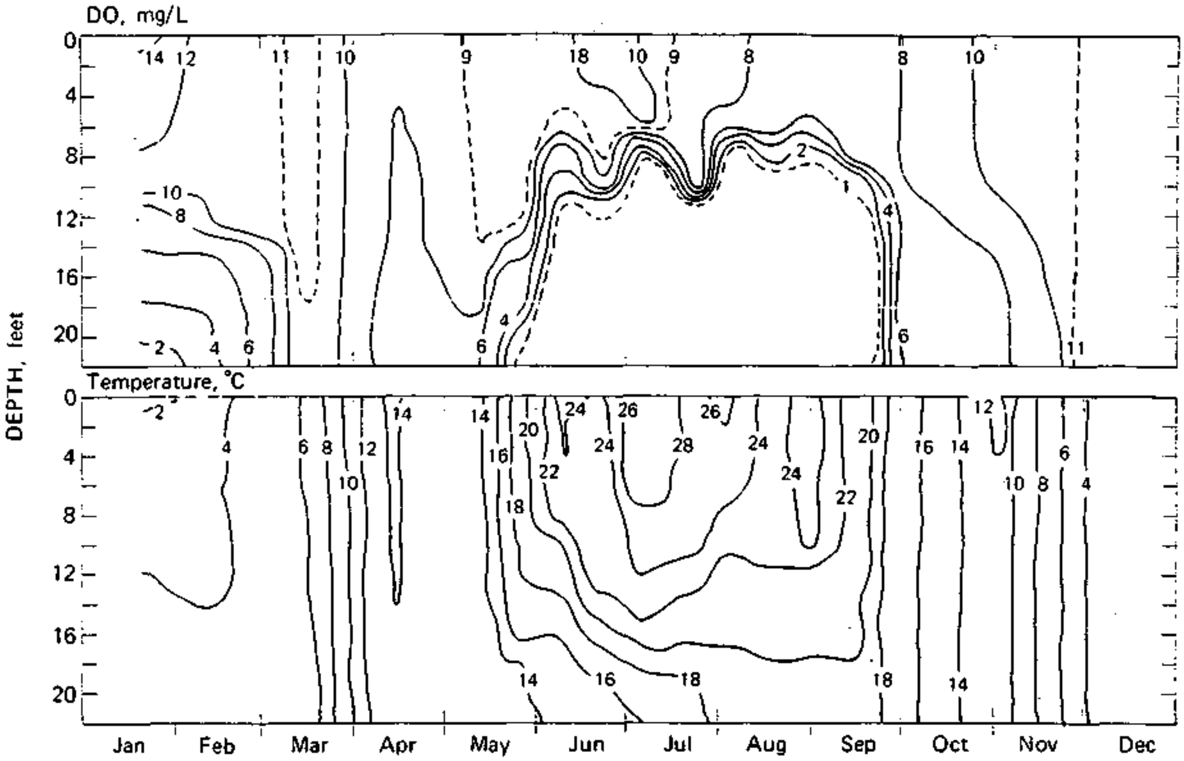

Figure 4. Isothermal and dissolved oxygen plots for station 1, 1981

during the summer months (figure 4). The maximum water temperature for station 1 (28 C) was observed on July 7, 1981, and the lake experienced the maximum temperature differential of 12°C between the surface and bottom waters on the same date. Thereafter, the intensity of stratification began to decrease. The lake was found to be uniform in temperature after the fall turnover on October 16, 1981.

Isothermal plots for the deep station (station 1) in Johnson Sauk Trail Lake for the period when the destratifier operated without prolonged operational interruption are shown in figure 5. In this figure and in all the subsequent plots representing the lake water quality characteristics under destratified conditions, observed data for the periods October through December 1984 and January through September 1985 were used. The maximum surface water temperature observed at station 1 during this period was 26.0°C on July 22, 1985, and the maximum temperature differential at this location was 2.0 C on June 24, 1985. Generally, the difference in water temperatures between the surface and near-bottom waters was less than 0.5 C during the summer months. All the observed temperature and DO data are included in appendix 1.

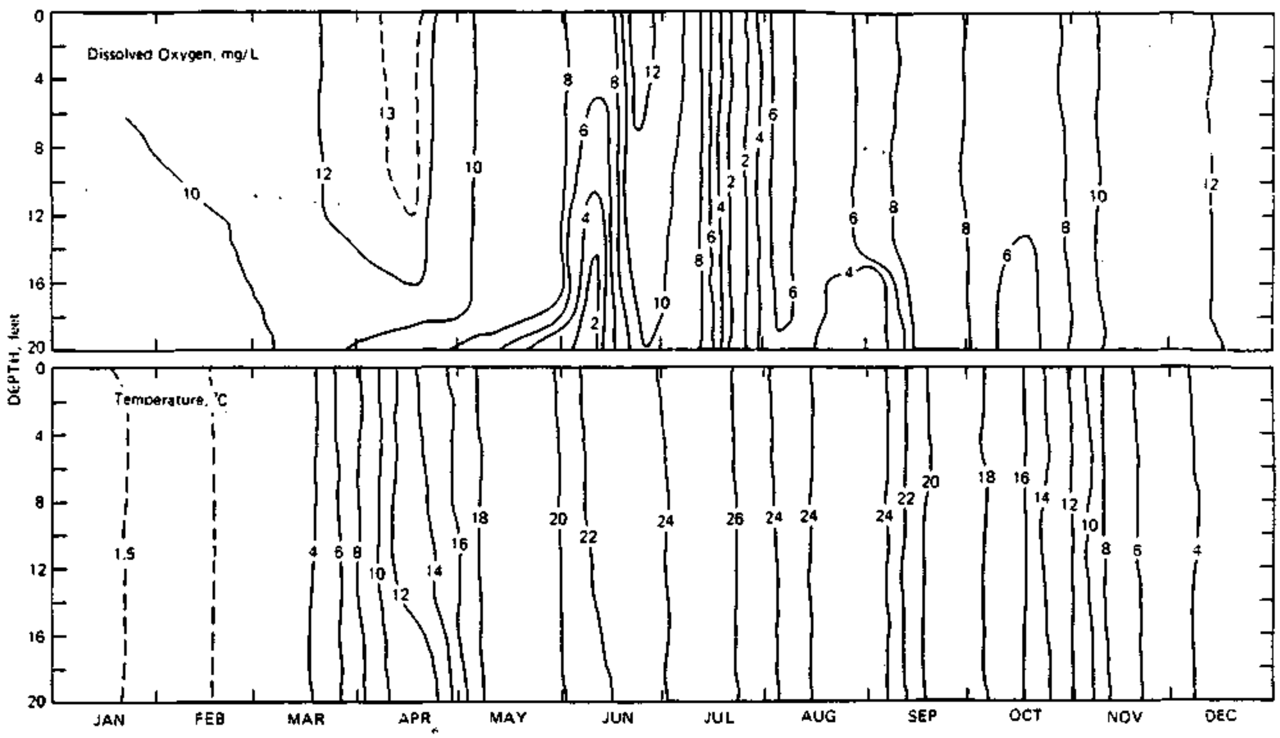

Figure 5. Isothermal and dissolved oxygen plots for station 1, January - September 1985 and October - December 1984

Isothermal plots for station 2 for the pre- and post-destratification periods are shown in figures 6 and 7, respectively. Figure 6 reveals that the lake tended to stratify at the shallow station in July 1981, at which time it had a temperature gradient of 2.8 C. The maximum temperature gradient observed during the destratification period was 2.5 C on June 10, 1985, when the unit was not operating due to power failure.

Figure 5, in conjunction with figure 4, clearly indicates that the mechanical destratifier effectively mixed the lake. Surface water temperatures were generally lower and the near-bottom water temperatures significantly higher than usual with destratification.

Selected vertical temperature profiles at station 1 for the years 1981 and 1984-1985 are shown in figure 8. Surface water temperatures were generally lower during the destratification period than during the pre-project period. Also the near-bottom water temperatures during the summer months were significantly higher when the lake was destratified .

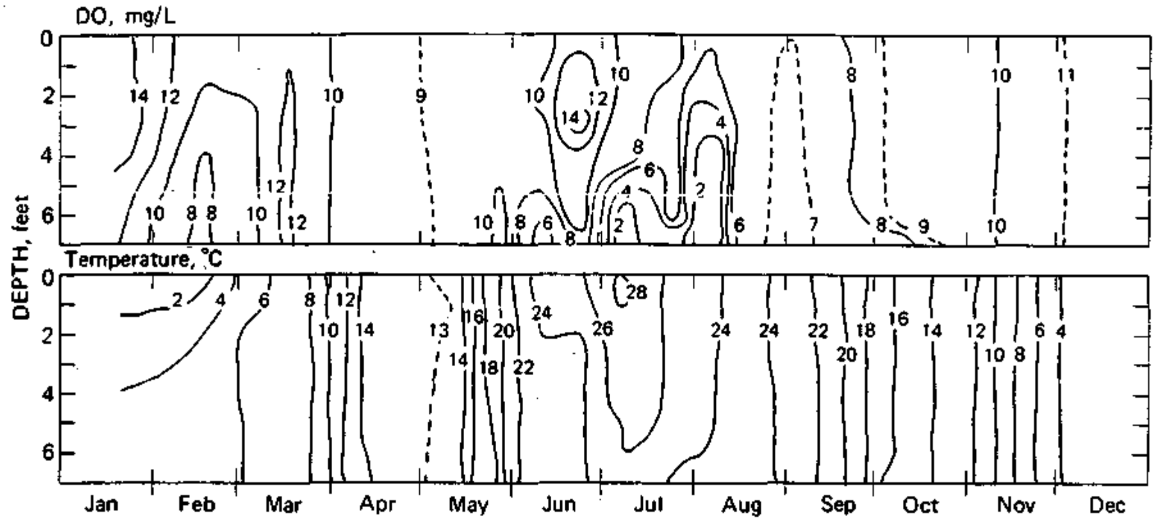

Figure 6. Isothermal and dissolved oxygen plots for station 2, 1981

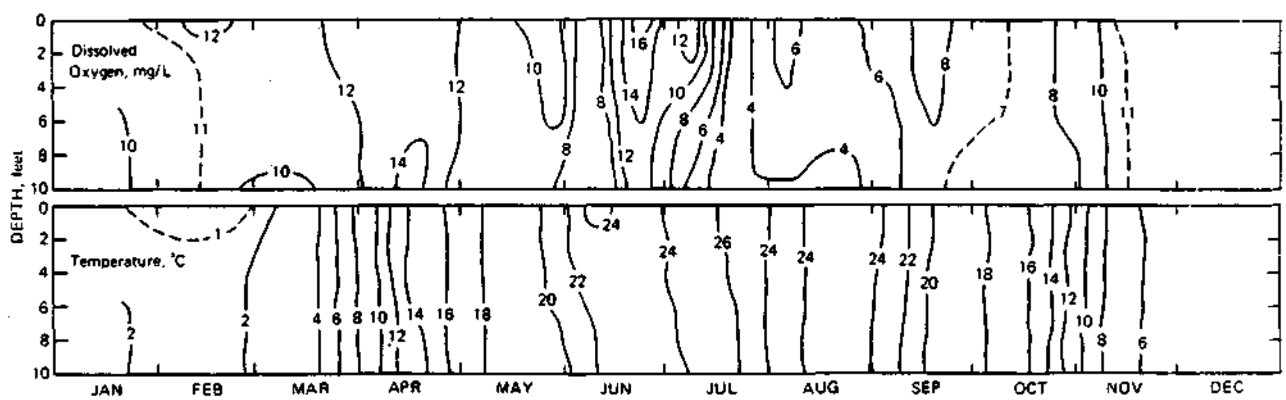

Figure 7. Isothermal and dissolved oxygen plots for station 2, January - September 1985 and October - December 1984

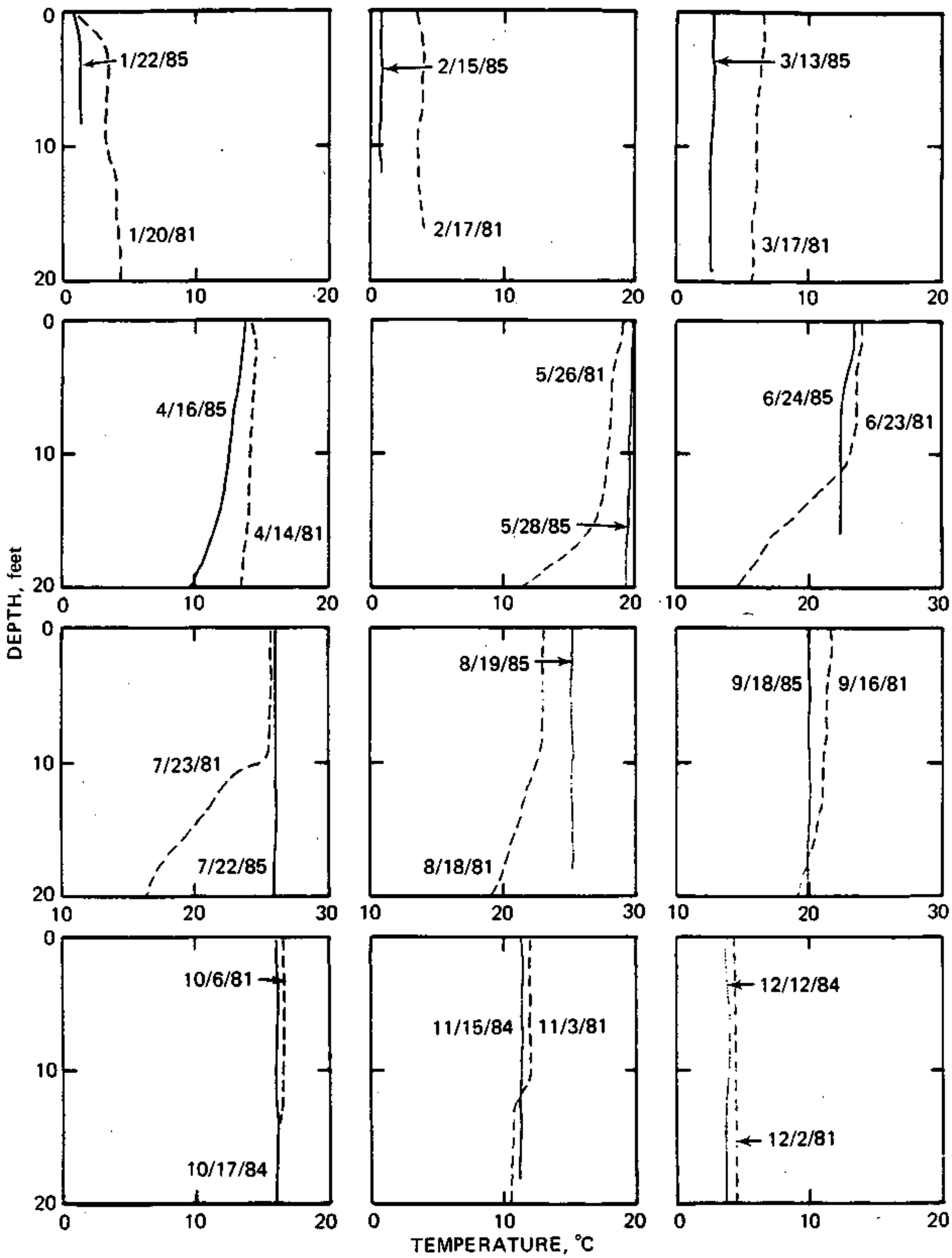

Figure 8. Temperature profiles at station 1 on selected dates, 1981, 1984, and 1985

Dissolved Oxygen. Where the depth of an impoundment or a lake is significant, the thermal stratification acts as an effective barrier against wind-induced mixing. The oxygen transfer to the deep waters is essentially confined to the molecular diffusion mechanism. As a result, when the benthic sediments exert a high oxygen demand, the oxygen resources of the hypolimnetic. zone are quickly exhausted. Anoxic conditions prevail in the lake bottom waters during the warm summer months. Hill et al. (1981) reported this to be true even in a lake with a 5-foot depth.

The isopleths of dissolved oxygen (DO) for the lake at station 1 for the pre- and post-destratification periods are shown in figures 4 and 5, respectively. During 1981, dissolved oxygen depletion began to occur during the early part of May. As the summer thermal stagnation intensified, the anoxic zone of hypolimnetic waters increased progressively, reaching a maximum during mid-July. The extent of this anaerobic zone started diminishing thereafter, and the DO concentration became uniform in the water column in late September. As is apparent from figure 4, the progression of this anoxic zone coincided with the progression of the thermal stratification in the lake.

During the period of peak stratification in 1981, the lake was totally anoxic at depths 8 feet from the surface and below. About 177 acre-feet or approximately 38% of the water volume of the lake was anoxic, severely restricting the habitat for desirable fish food organisms and fish. During the summer months, adequate oxygen levels did not generally exist at depths below 10 feet from the surface.

Isopleth plots for the post-destratification period (figure 5) indicate that adequate oxygen levels were maintained throughout the summer season at station 1 except for a brief period in early June 1985 when the DO levels in the near-bottom waters were below 2 mg/L. This was primarily because the destratifier was shut down from June 8 to June 11, 1985, due to power failure. The observations for DO at station 1 were made on June 10, 1985. The lake tended to become anoxic in the deeper waters because of the high oxygen demand exerted by the bottom sediments. Temperature data (appendix 1) for this date indicate that a thermal gradient existed in the deep part of the lake, preventing the mixing of oxygen-rich upper layers of the lake waters with the waters in the deeper zone. Except for this single episode, oxygen levels in the deeper waters remained comparable to the DO levels in the upper layers.

The reasons for the disastrously low DO observed throughout the lake on July 22, 1985 (appendix 1) could not be definitively ascertained. This phenomenon may be due to a possible algal die-off between the lake monitoring visits of July 8 and July 22, 1985.

Figure 9 shows selected vertical DO profiles in the lake at station 1 for the years 1981 and 1984-1985. It is apparent that oxic conditions in the lake bottom waters were greatly improved with the destratifier in operation during the summer months. With the destratifier operating, anoxic conditions in the lake bottom waters were eliminated, enhancing the fish habitat to 100% of the lake volume during the summer months.

Secchi Disc Transparency. Secchi disc transparency is a measure of the lake water clarity or its ability to allow light transmission. Transparency is related to water color and suspended sediments consisting of silt, clay, algae, and other organic debris. The mean value for transparency at station 1 observed during 1981 was 50 inches and the range was 6 to 103 inches. Secchi disc readings during June, July, and August 1981 were in the range of 18 to 51 inches. The mean and range of values for the post-project period CSeptember 1984 - September 1985; table 3) were 42 inches and 18-107 inches, respectively. Even though the overall mean transparency was lower during the post-project period, the minimum and maximum values were higher during this period. Also, the maximum secchi disc reading observed during the summer months of 1985 C72 inches) was significantly higher than that observed during the summer months of 1981 (51 inches). The temporal variations in secchi disc readings and other water quality parameters are shown in figure 10 for both 1981 and 1984-1985. The observed secchi disc values and other relevant raw data are included in appendix 2.

Turbiditv. High turbidity affects the aesthetic quality of a body of water. Algae, clastic materials derived from the drainage basin, sediments in lakes stirred by wind and waves, and detrital remains of algae and aquatic and terrestrial plants and animals are some of the factors which cause turbidity in lake waters.

The mean and range of turbidity values observed at the surface of station 1 for different time periods during the monitoring of Johnson Sauk Trail Lake are shown in table 3. Values for mid-depth and near-bottom water samples at station 1 are shown in tables 4 and 5, respectively, along with the values for several other water quality parameters. Temporal variations in turbidity in the surface, mid-depth, and near-bottom waters of station 1 are shown in figures 10, 11, and 12, respectively, along with the plots for several other water quality parameters.

The mean turbidity values of the surface and mid-depth samples were higher for the post-project period (September 1984 - September 1985) than for January - December 1981, but the maximum observed values were significantly less in all cases. The mean turbidity values for the period June to August 1985 (tables 3, 4, and 5) were higher than for the corresponding period in 1981, and the minimum and maximum values were invariably higher. The

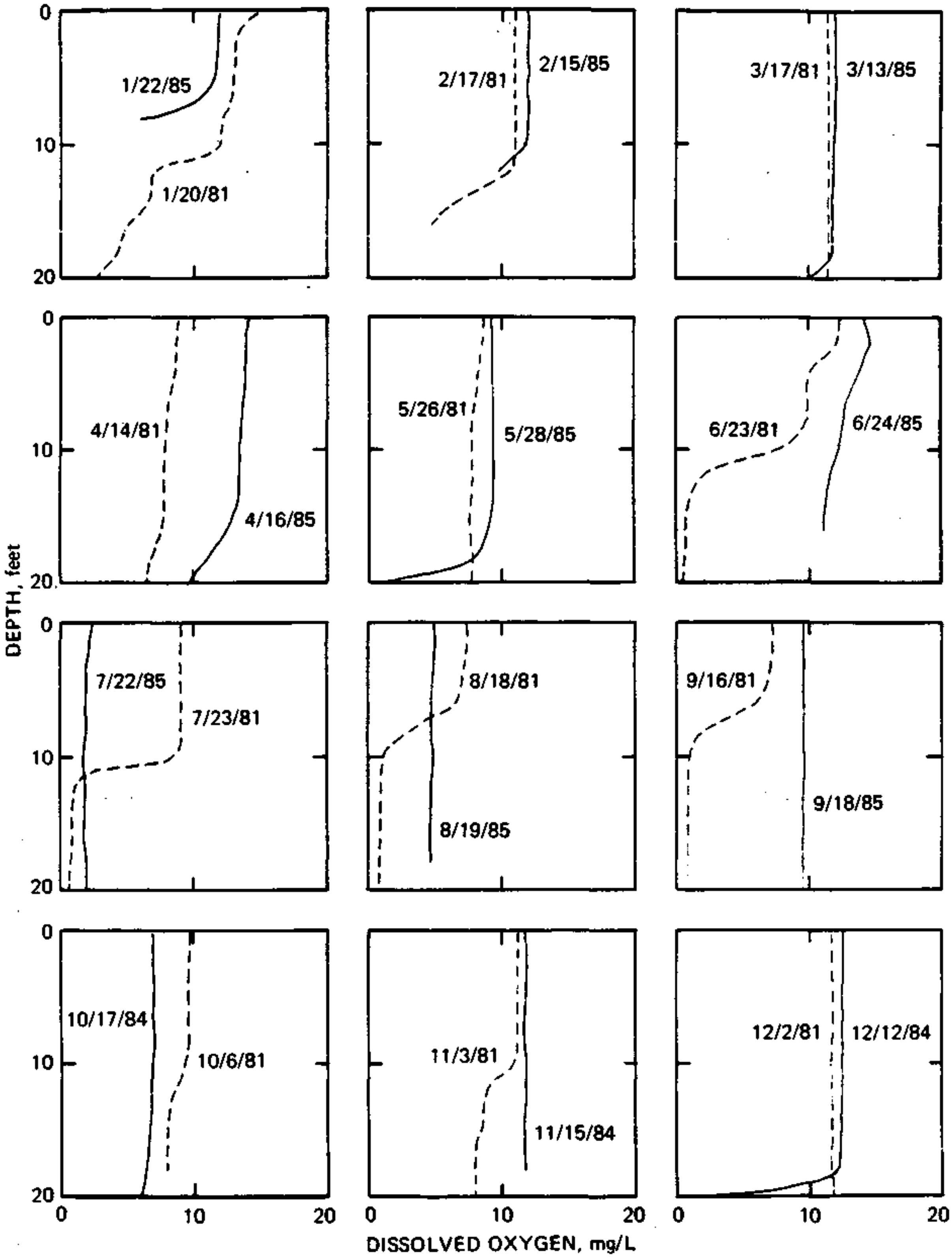

Figure 9. Dissolved oxygen profiles at station 1 on selected dates, 1981, 1984, and 1985

Table 3. Summary of Surface Water Quality Characteristics

Parameters	Jan. - Dec. 1981 Mean	Jan. - Dec. 1981 Range	Sep. 1984-Sep. 1985 Mean	Sep. 1984-Sep. 1985 Range	June - Aug. 1981 Mean	June - Aug. 1981 Range	June - Aug. 1985 Mean	June - Aug. 1985 Range
Secchi readings (inches)	50	6-103	42	18-107	33	18-51	34	18-72
Turbidity (NTU)	7.7	0.4-60.2	14.2	4-30	5.8	4.0-9.2	16.5	5.0-30.0
pH (dimensionless)		7.9-9.6		8.0-9.4		8.7-9.6		8.6-9.4
Alkalinity	157	67-187	177	156-211	157	143-171	172	160-186
Conductivity (µmho/cm)	281	98-371	342	284-400	311	195-368	349	285-391
Total phosphate-P	0.07	0.03-0.21	0.15	0.02-0.32	0.07	0.03-0.10	0.23	0.12-0.32
Dissolved phosphate-P	0.02	0.01-0.04	0.08	0.01-0.23	0.02	0.01-0.04	0.13	0.04-0.23
Total ammonia-N	0.19	0.04-0.42	0.23	0.05-0.80	0.18	0.03-0.26	0.33	0.09-0.80
Nitrate-N	0.10	0.03-0.27	0.10	0.00-0.40	0.06	0.04-0.10	0.06	0.00-0.09
Total Kjeldahl-N	1.01	0.52-2.39	1.31	0.16-2.28	1.36	0.82-2.39	1.74	0.88-2.28
Dissolved solids	242	72-296	252	110-394	245	190-276	250	238-272
Total suspended solids	9.3	0-52	14.6	1-33	9.2	5-13	19.0	8-29
Volatile suspended solids	6.2	0-12	8.4	0-19	8.3	3-14	12.7	6-19

Note: Values in mg/L unless othervise indicated

Table 4. Summary of Mid-Depth Water Quality Characteristics

Parameters	Jan. - Dec. 1981 Mean	Jan. - Dec. 1981 Range	Sep. 1984-Sep. 1985 Mean	Sep. 1984-Sep. 1985 Range	June - Aug. 1981 Mean	June - Aug. 1981 Range	June - Aug. 1985 Mean.	June - Aug. 1985 Range
Turbidity (NTU)	7.9	1.4-56.8	15.1	3.0-28.0	7.2	4.9-10.2	17.0	6.0-28.0
pH (dimensionless)		8.1-9.5		8.0-9.4		8.1-9.5		8.6-9.4
Alkalinity	168	139-195	177	156-208	157	139-171	171	162-186
Conductivity (µmho/cm)	291	185-370	340	282-404	315	185-370	348	285-389
Total phosphate-P	0.09	0.04-0.25	0.16	0.02-0.31	0.12	0.05-0.24	0.25	0.12-0.31
Dissolved phosphate-P	0.03	0.01-0.16	0.09	0.01-0.23	0.05	0.02-0.16	0.14	0.05-0.23
Total ammonia-N	0.30	0.12-1.16	0.24	0.03-0.83	0.48	0.14-1.16	0.35	0.10-0.83
Nitrate-N	0.10	0.03-0.17	0.08	0.00-0.34	0.09	0.06-0.15	0.05	0.00-0.09
Total Kjeldahl-N	1.10	0.57-2.25	1.42	0.17-3.05	1.49	0.71-2.25	2.06	0.78-3.05
Dissolved solids	256	196-306	244	110-302	252	196-286	249	240-268
Total suspended solids	12.9	0-83	15.6	3-37	12.3	6-20	20.3	8-32
Volatile suspended solids	7.6	0-18	8.1	1-19	10.1	4-18	11.0	6-19

Note: Values in mg/L unless otherwise indicated

Table 5. Summary of Near-Bottom Water Quality Characteristics

Parameters	Jan. - Dec. 1981 Mean	Range	Sep. 1984-Sep. 1985 Mean	Range	June - Aug. 1981 Mean	Range	June - Aug. 1985 Mean	Range
Turbidity (NTU)	35.1	1.6-377.0	31.1	7.0-164.0	13.2	3.5-37.8	21.3	9-38
pH (dimensionless)		7.6-8.6		8.0-9.4		7.6-8.3		8.7-9.4
Alkalinity	188	126-250	178	156-210	207	183-250	172	162-186
Conductivity (µmho/cm)	312	214-445	343	281-396	363	245-445	351	294-390
Total phosphate-P	0.30	0.03-0.95	0.19	0.05-0.35	0.47	0.07-0.76	0.26	0.13-0.35
Dissolved phosphate-P	0.16	0.01-0.49	0.09	0.01-0.22	0.31	0.04-0.49	0.14	0.06-0.22
Total ammonia-N	1.03	0.17-3.41	0.27	0.04-0.93	1.85	0.35-3.41	0.40	0.14-0.93
Nitrate-N	0.12	0.05-0.34	0.08	0.00-0.34	0.09	0.05-0.18	0.05	0.00-0.10
Total Kjeldahl-N	1.76	0.75-4.36	1.62	0.23-2.54	2.59	0.81-3.97	1.98	0.74-2.54
Dissolved solids	267	192-306	244	110-304	281	192-324	250	240-264
Total suspended solids	27.6	0-158	40.3	7-204	22.8	5-47	27.3	10-42
Volatile suspended solids	8.5	0-22	12.3	1-30	10.3	4-16	12.7	8-18

Note: Values in mg/L unless otherwise indicated

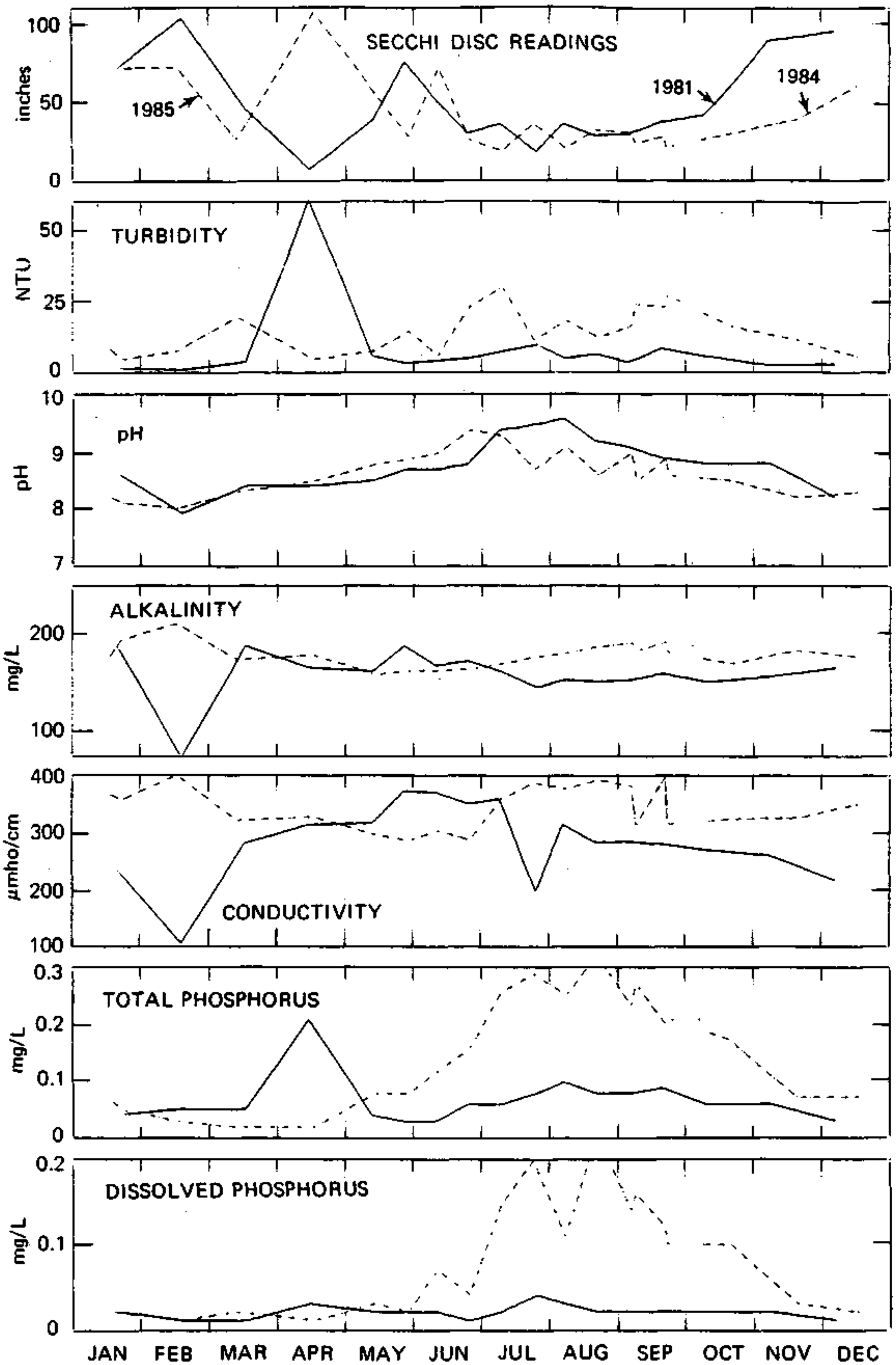

Figure 10. Temporal variations in near surface water quality characteristics at station 1 in 1981, January - September 1985, and October - December 1984

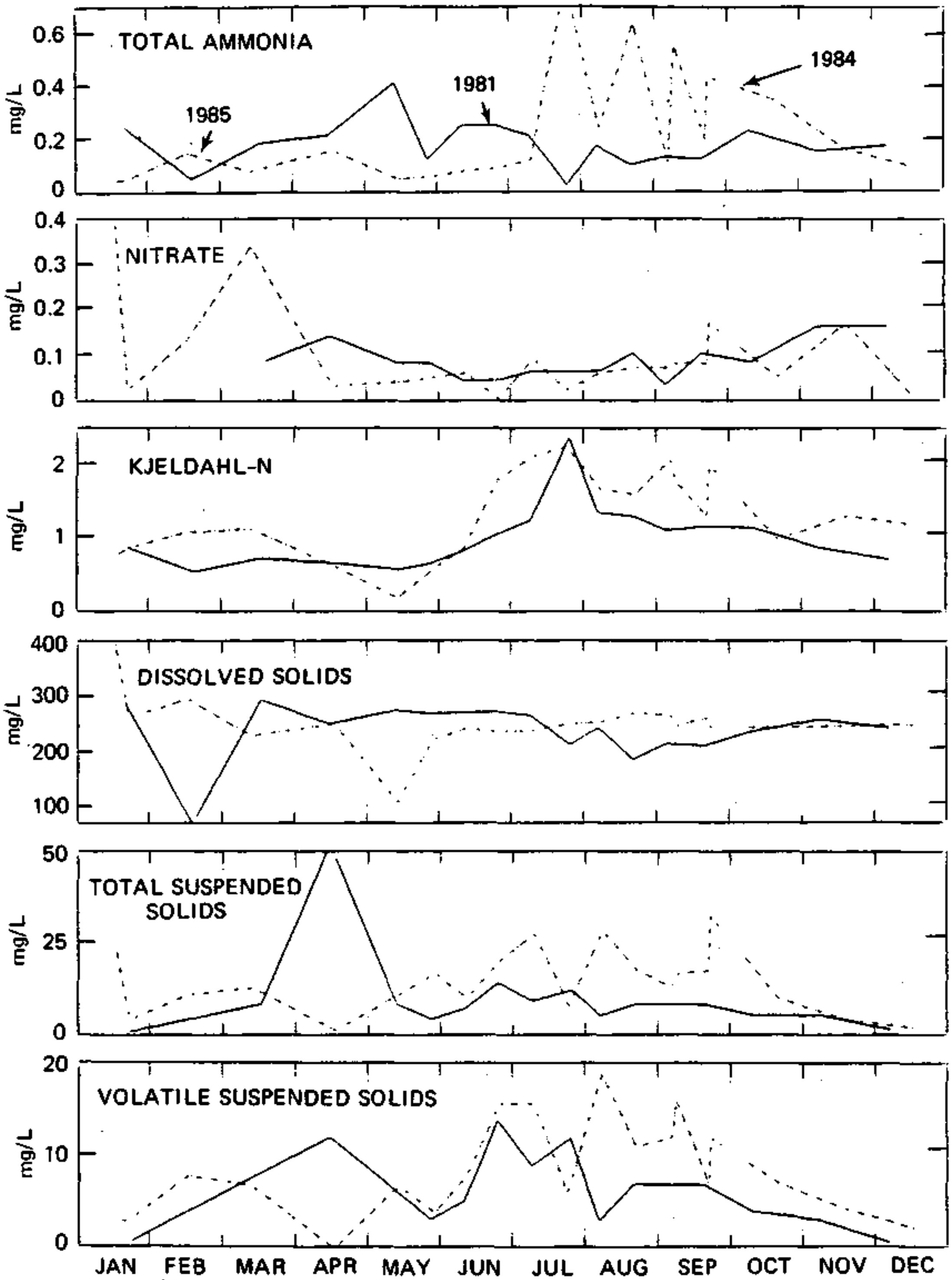

Figure 10. Concluded

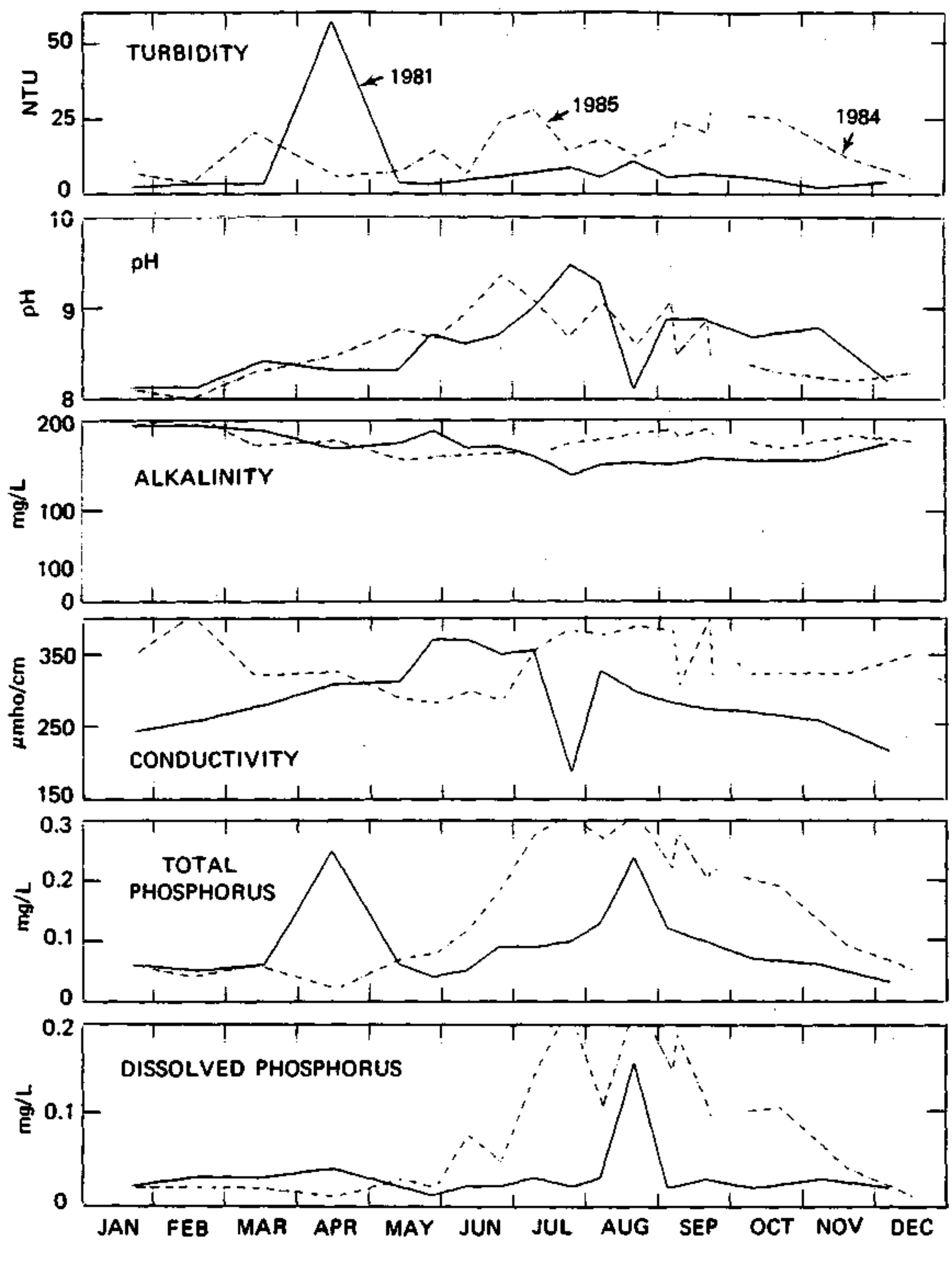

Figure 11. Temporal variations in mid-depth, water quality characteristics at station 1 in 1981, January - September 1985, and October - December 1984

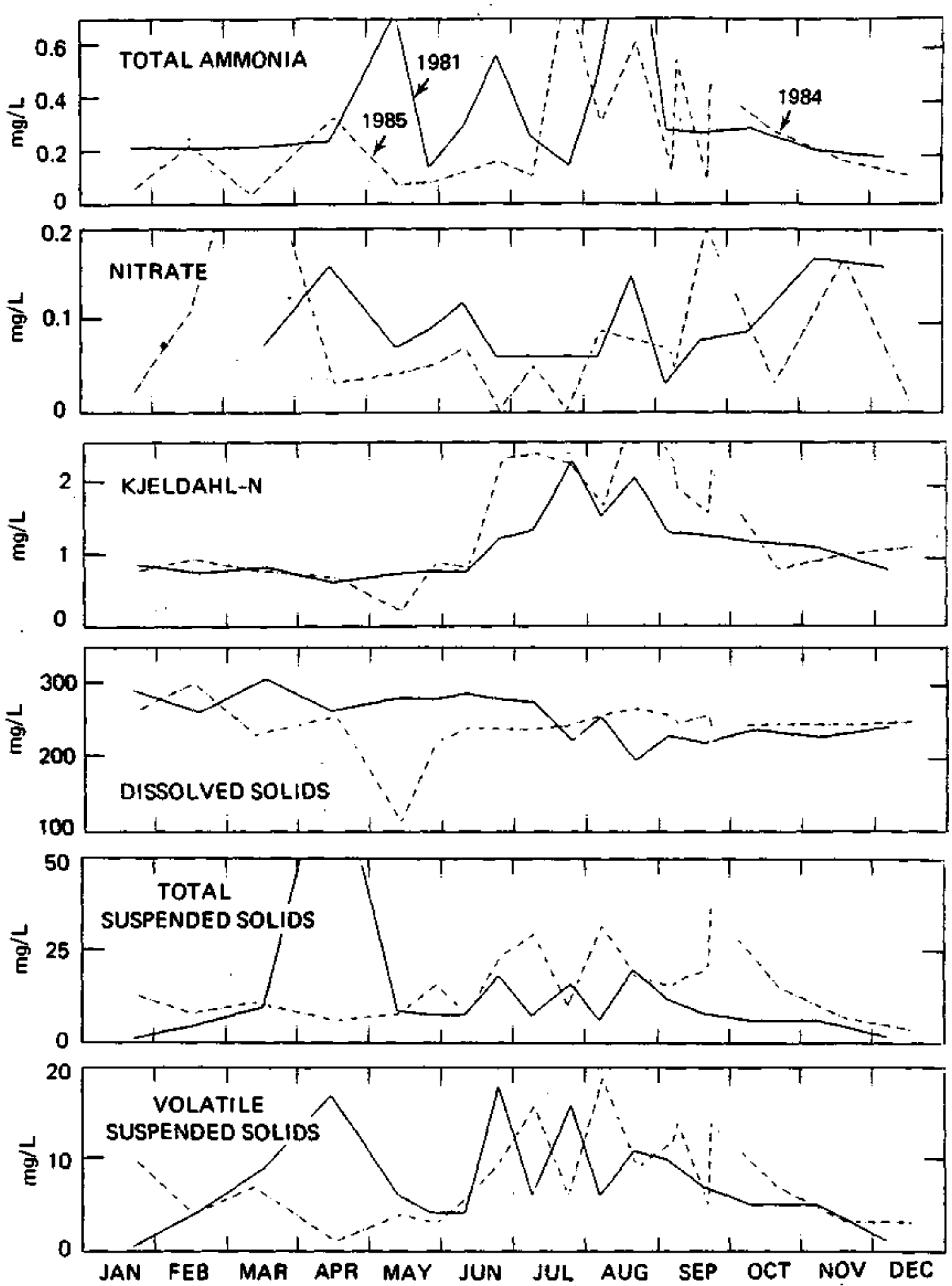

Figure 11. Concluded

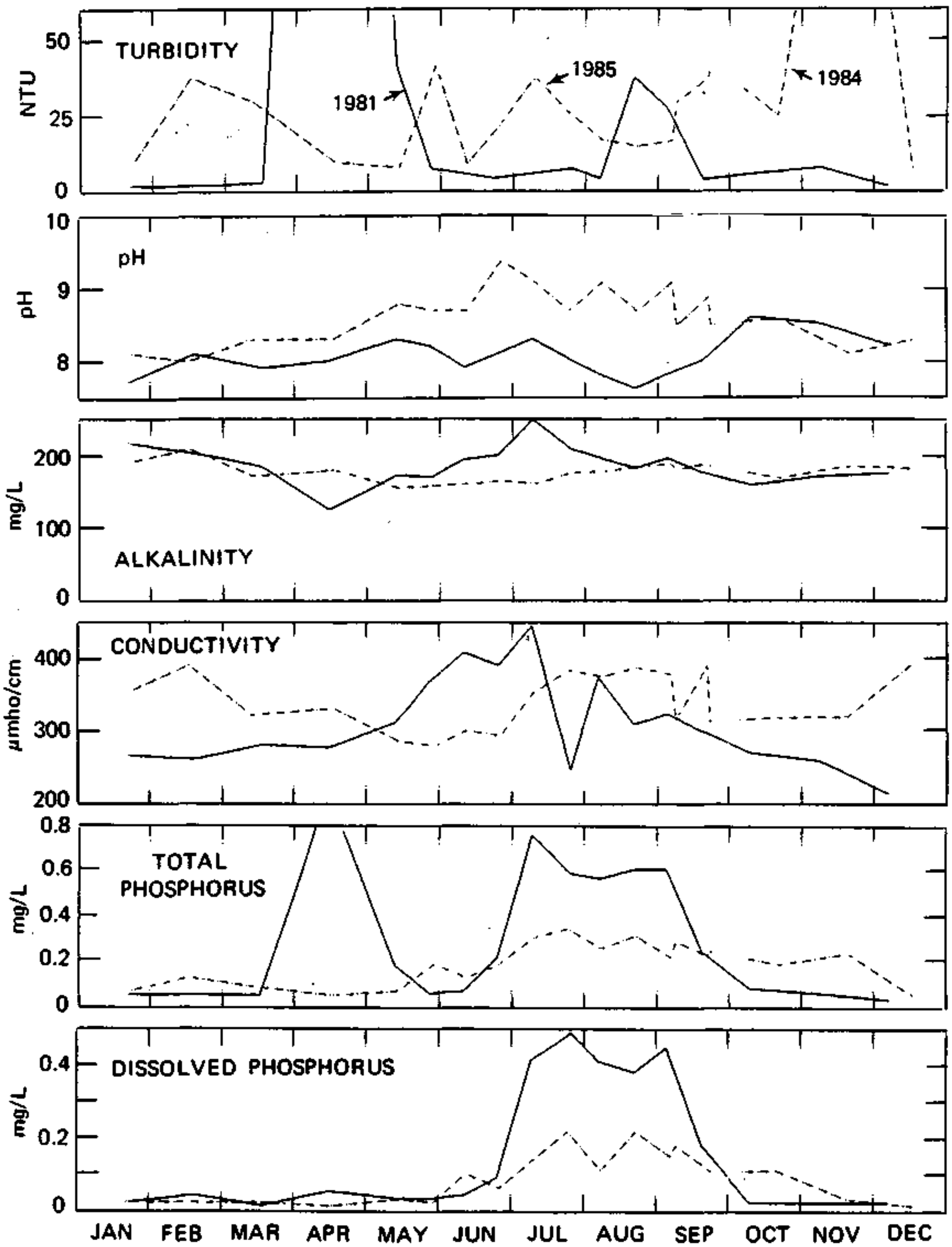

Figure 12. Temporal variations in near-bottom water quality characteristics at station 1 in 1981, January - September 1985, and October - December 1984

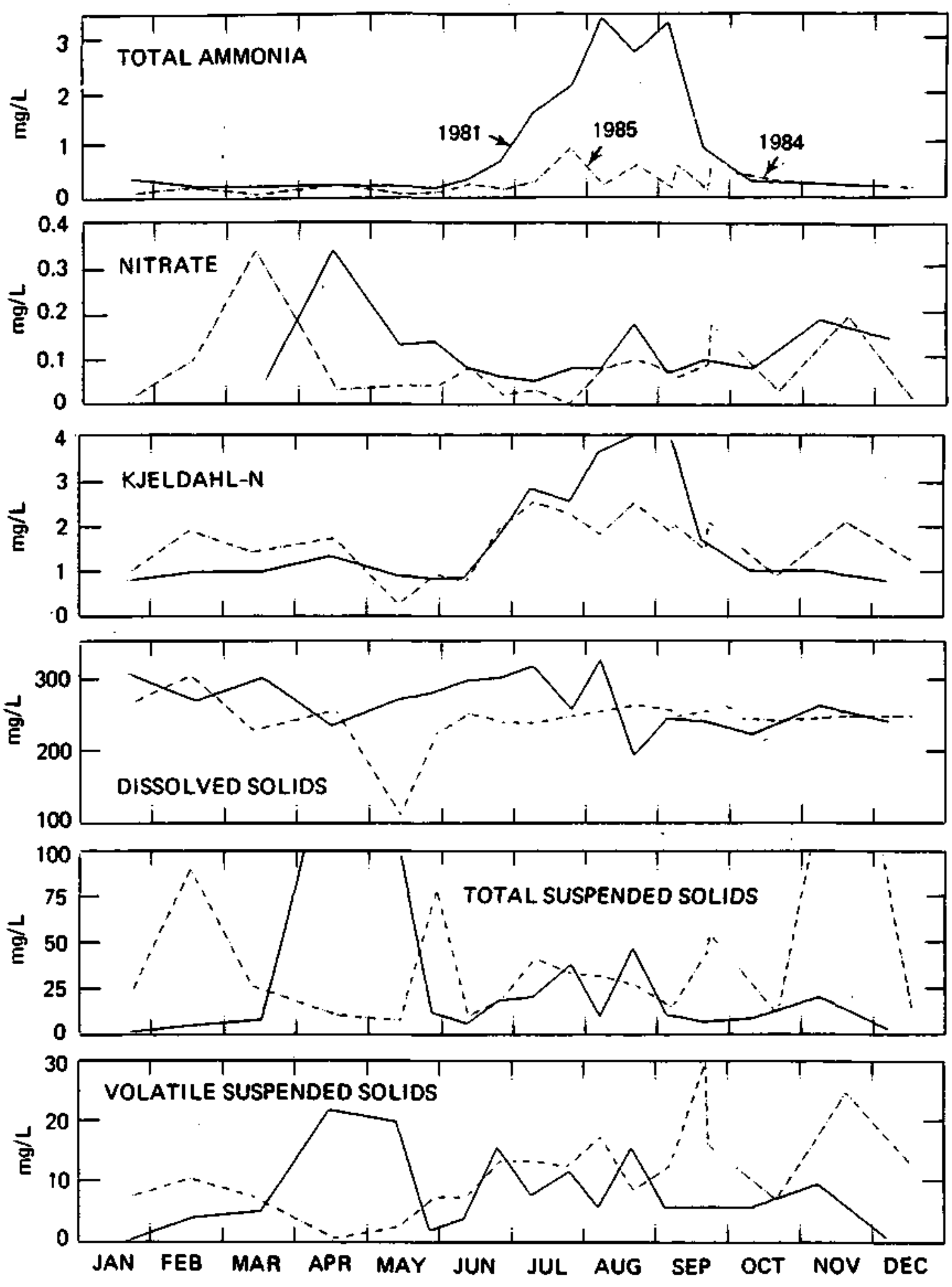

Figure 12. Concluded

temporal variations in turbidity plots (figures 10, 11, and 12) for surface, mid-depth, and near-bottom values reveal that these were mostly higher in 1984-1985 than in 1981.

An examination of the precipitation data given below for the Johnson Sauk Trail Lake watershed for 1981 and those reported for nearby Kewanee, IL, for 1981 by the National Oceanic and Atmospheric Administration indicate that there was very little spatial variation in the monthly total rainfalls (in inches) at these two locations.

	Apr	May	Jun	Jul	Aug	Sep
Johnson Sauk Trail Lake, 1981	6.94	2.29	6.15	3.35	8.28	3.45
Kewanee, 1981	*	3.01	5.12	4.01	8.46	3.51
Kewanee, 1985	1.00	2.03	2.99	2.90	2.79	1.85

* No data available

Comparison of the Johnson Sauk Trail Lake 1981 data with the Kewanee 1985 data reveals that the rainfall in the watershed would have been significantly less in 1985 than in 1981. Consequently the increase in turbidity in 1985 is not likely related to rainfall-runoff events.

The mean suspended solids concentrations during summer months for the pre- and post-project periods at the surface were 9.2 and 19.0 mg/L respectively (table 3). The inorganic fractions of the nonfilterable solids were 9.8 and 33.2%, respectively, during these periods. These facts indicate that the increase in turbidity was probably due to the disturbance of fine bottom sediments by the downflow jet of the mechanical destratifier. This could have been avoided by decreasing the pitch of the blades of the impeller to such an extent that the downflow jet would just graze the bottom instead of scouring it.

However, it should be pointed out that the secchi disc transparencies during the summer months of 1985 were higher than for the corresponding period in 1981. Lake recreational activities are at the highest level during the summer months.

Chemical Characteristics

pH and Alkalinity. It is generally considered that pH values above 8.0 in natural waters are produced by a photosynthetic rate that demands more carbon dioxide than the quantities furnished by respiration and decomposition. Photosynthesis by aquatic plants uses carbon dioxide, removing it from bicarbonate, when no free carbon dioxide exists in the water medium. This increase in pH with the concomitant decrease in alkalinity generally follows algal blooms during summer months. At the same time, active anaerobic decomposition of the lake bottom sediments under stratified anoxic conditions during summer months tends to reduce pH and increase bicarbonate alkalinity in the near-bottom waters.

These trends are clearly perceptible in figures 10 and 12 for the pre-destratification period. These trends were reversed during the summer of 1985, probably due to total lake mixing and decreased algal biomass and activity in the photic zone. pH values were lower in summer and the alkalinity values were higher. pH values were significantly higher in the near-bottom waters, and the alkalinity values were considerably lower, reflecting destratification and decreased mineralization of lake bottom sediments under aerobic conditions compared to anaerobic conditions. The overall surface mean alkalinity value was higher in the 1984-1985 period than in 1981 (table 3), and the overall near-bottom-water mean value was lower (table 5).

Conductivitv. Specific conductance provides a measure of a water's capacity to convey electric current and is used as an estimate of the dissolved mineral quality. This property is related to the total concentration of ionized substances in water and the temperature at which the measurement is made.

The mean conductivity values for the lake water samples during 1981 were 281 μmho/cm for the surface, 29I μmho/cm for the mid-depth, and 312 μmho/cm for the near-bottom waters. These values for the post-destratification period (September 1984 September 1985) were respectively 342 μmho/cm, 340 μmho/cm, and 343 μmho/cm. All the values were reduced to a common base temperature of 25°C. The temporal variations in conductivity for the three sampling locations at station 1 are shown in figures 10 to 12.

Phosphorus. Phosphorus as phosphate may occur in surface waters or ground waters as a result of leaching from minerals or ores, the natural process of degradation of vegetative matter, agricultural drainage, and municipal and industrial discharges. Phosphorus is an essential nutrient for plant and animal growth and, like nitrogen, it passes through cycles of decomposition and photosynthesis. Sawyer (1952) concluded that aquatic blooms are likely to develop in lakes during summer months when concentrations of inorganic nitrogen and inorganic phosphorus are in excess of 0.3 and 0.01 mg/L, respectively. These critical levels for nitrogen and phosphorus concentrations have been accepted and widely quoted in the scientific literature.

Summaries of the observations for total and dissolved phosphorus in the lake are given in tables 3, 4, and 5. Temporal variations in phosphorus content in the lake are depicted in figures 10, 11, and 12.

The surface mean total phosphorus concentration was twice as high during the 1984-1985 period as in 1981. During June - August 1985 it was three times higher than in June - August 1981 (0.23 mg/L compared to 0.07 mg/L). The ranges of total phosphorus values for these two June-August periods were 0.12 to 0.32 mg/L and 0.03 to 0.10 mg/L, respectively. Dissolved phosphorus levels were also higher in 1984-1985. Although the phosphorus concentrations were higher most of the time in the 1984-1985 period than in 1981 (figure 10), the number of algae in the lake was generally less, as will be discussed later.

The observations made for surface phosphorus concentrations are generally applicable to mid-depth phosphorus concentrations (table 4) also. However, for the near-bottom waters (table 5), the mean total phosphorus concentration for the period September 1984 to September 1985 was only 63% of the mean value for the year 1981. During the summer months of 1985, it was only about 55% of the mean value for the summer months of 1981. Reductions in dissolved phosphorus concentrations were much more pronounced (table 5 and figure 12) during the destratification period. Oxic conditions of the near-bottom waters as a result of destratification may have caused reductions in the rate of phosphorus release from the bottom sediments. Redistribution of phosphorus throughout the water column from total mixing may have also lowered phosphorus concentrations in bottom waters as compared to pre-implementation levels.

The ratio of dissolved phosphorus to total phosphorus in the surface water samples during 1981 varied from 0.14 to 0.67 with a mean value of 0.35. When the primary productivity in the lake was relatively high (June - August 1981), the ratio varied from 0.17 to 0.50 with a mean of 0.29. For the period September 1984 to September 1985 the comparable values for the surface waters were 0.25 to 1.00 with a mean of 0.50, and for the period June August 1985 they were 0.25 to 0.69 with a mean of 0.56.

The dissolved phosphorus to total phosphorus ratio for the near-bottom waters varied from 0.05 to 0.83 with a mean of 0.50 in 1981. Corresponding values during the lake management period were 0.11 to 0.77 and 0.41.

Nitrogen. Nitrogen in natural waters is generally found in the form of nitrate, organic nitrogen, and ammonia-nitrogen. Nitrates are the end product of the aerobic stabilization of organic nitrogen, and as such they occur in polluted waters that have undergone self-purification or aerobic oxidation processes. Nitrates also occur in percolating ground waters. Ammonia-nitrogen, being a constituent of the complex organic nitrogen cycle, results from the decomposition of nitrogenous organic matter, or its occurrence in natural waters may be related to agricultural practices. It can also result from municipal and industrial waste discharges to receiving waters.

The mean and range of values for ammonia, nitrate, and Kjeldahl-nitrogen in the lake are included in tables 3, 4, and 5, and the temporal variations in these parameters are shown in figures 10, 11, and 12. During 1981, the mean total inorganic nitrogen was always equal to or higher than the suggested critical concentration CO.3 mg/L} for nitrogen. The mean values for total ammonia-nitrogen were 0.19 mg/L at the surface and 1.03 mg/L at the bottom. Nitrate-nitrogen mean values were 0.10 mg/L at the surface, 0.10 mg/L at mid-depth, and 0.12 mg/L at the bottom. Kjeldahl-nitrogen mean values increased spatially toward the bottom of the lake. Ammonia and Kjeldahl-nitrogen concentrations increased several fold at the mid-depth and deep sampling points during the summer thermal stagnation period as a result of intense anaerobic decomposition of organic debris occurring on the lake bottom.

During the 1984-1985 period, the mean total inorganic nitrogen was again higher than the suggested critical concentration for nitrogen. The mean values of total ammonia were 0.23 mg/L at the surface and 0.27 mg/L at the bottom, corresponding to the preproject values of 0.19 mg/L and 1.03 mg/L, respectively. Likewise, even though Kjeldahl-nitrogen showed a trend of increasing values toward the lake bottom during the post-project period, the increase was much less than in the preproject period. Mean values for nitrate were comparable. The total nitrogen to total phosphorus ratio for the September 1984 to September 1985 period varied from 3 to 78 with a mean of 19. For the preproject period, the ratio varied from 5 to 37 with a mean of 23. Nitrogen was not a limiting factor for algal growth in the lake.

Dissolved and Suspended, Solids. Evidence in the literature indicates that dissolved solids content in lake waters is an important index of potential productivity in the lake, because no element, ion, or compound is likely to be a limiting factor on algal production when the dissolved solids content is high.

Dissolved solids concentrations found in Johnson Sauk Trail Lake are typical of Illinois lakes. The data presented in tables 3, 4, and 5, and figures 10, 11, and 12 do not reveal any discernible trends in the dissolved, suspended, and volatile solids values. The means of suspended solids values for the 1984-1985 period were higher in all the sampling locations than in the 1981 period. The percent of mean volatile fraction of the suspended solids at the surface was 56 in the 1984-1985 period versus 67 in 1981. These facts suggest that the downflow jet created by the destratifier might have scoured the lake bottom, resuspending the sediments.

Chemical Treatment. Chemical treatment in conjunction with artificial destratification was undertaken to control algal blooms and more specifically to control problem-causing blue-green algal blooms. The results of copper analyses of water samples obtained after the application of chelated copper sulfate are shown in table 6. The results of copper analyses indicate that copper was dispersed uniformly throughout the lake. The background copper level in the lake was found to be about 0.004 mg/L expressed as copper. Mackenthun (1969) and Muchmore (1973) indicate the heed of a soluble copper concentration of 0.1 to 0.3 mg/L as Cu in lake waters for algicidal effectiveness.

The single point application of the chemicals and the subsequent dispersal with the aid of the aerator appear to be effective and economical. This method also prevents inadvertent local overdosing of the algicide by manual application, resulting in fish kills, as has been reported in the literature. Results comparable to the ones reported here are also reported by Kothandaraman and Evans (1982) for Lake Eureka, which is similar to Johnson Sauk Trail Lake.

Biological Characteristics

Phvtoplankton. The total algal counts and the species distribution of algae found at station 1, as well as chlorophyll-a levels, are shown in table 7. During 1981, except for the observations during May, algal counts in the lake were found to be of bloom proportion (≥ 500 counts/mL), with blue-green algae the dominant algae in every case. The peak chlorophyll-a concentration (80 µg/L) was observed on July 7.

The data for summer 1985 (table 7) reveal that the lake had algal numbers of bloom proportions on only three of the ten occasions and also that blue-greens were the dominant species in only three instances. The algal densities found in the lake were significantly less in 1985 than in 1981. Chlorophyll-a levels were 17-55% lower in 1985 than in 1981 on 7 of the 10 sampling dates. The chlorophyll-a concentrations were more than 50%

Table 6. Distribution of Copper Ion in Johnson Sauk Trail Lake after Chemical Application

Dates of Sample Collection	Station 1 Surface	Station 1 2 feet	Station 2 Surface	Station 2 2 feet	Station 3 Surface	Station 3 2 feet
*8/8/84	0.06	0.05	0.06	0.06	0.06	0.06
+6/28/85	0.06	0.05	0.03	0.03	0.05	0.05

Note: Copper (Cu^{2+}) concentrations, mg/L
* Samples collected 48 hours after algicide application
+ Samples collected 24 hours after algicide application

Table 7. Algae Types and Densities and Chlorophyll-a Concentrations
in Johnson Sauk Trail Lake
(Algal densities in counts per milliliter)

1981								1985							
Date	BG	G	D	F	0	Total	Chlorophyll-a (µg/L)	Date	BG	G	D	F	0	Total	Chlorophyll-a (µg/L)
5/12	150	45	75			270	20	5/13		265	375	45	10	695	11
5/26	280					280	30	5/28	95		320	55	5	475	17
6/09	900				5	905	40	6/10	125	50	10	45		230	18
6/23	2645	395	100			3140	70	6/24	2630					2630	126
7/07	4630	1200	345	325		6500	80	7/08	160	30	40	10		240	124
7/23	5950	735	600	460		7745	67	7/22	715	50	75	5		845	28
8/04	8620	870	660	315		10465	53	8/05			390	75		465	115
8/18	20590	495	525	345		21955	40	8/19		230			10	240	25
9/01	10280	360	410	640	390	12080	47	9/03		70	150	10	10	240	39
9/16	16000		75		40	16115	40	9/18		30	30		5	65	24

Note: BG = blue-greens; G = greens; D = diatoms; F = flagellates; and 0 = others higher on two occasions during 1985 than the peak value observed for 1981. There apparently is no correlation between chlorophyll-a and the counts of algae found in Johnson Sauk Trail Lake.

A substantial algal bloom (2630 counts/mL, 100% blue-greens) occurred in late June following weed harvesting in early June. Subsequent application of algicide on June 28, 1985 brought the blue-greens under control. Greens or diatoms were the dominant species on six of the ten observations made for algae. The phytoplankton data and the biovolume information are included in appendix 3.

Benthic Oraanisms. The types and densities of benthic macroinvertebrate communities in the lake sediments are given in table 8. There was a significant decrease in *Chaoborus* counts in 1985 compared to those in 1981. These organisms prefer quiescent anoxic conditions to proliferate. With destratification, these conditions in the lake were altered. Predation could also be a factor in their reduced population density. There were no Tubificidae found at either station 1 or 2 during 1985. However, Ceratopogonidae, which were absent in 1981 at station 1, were found there during 1985. Harvesting of macrophytes could have contributed to the decline of the benthic population at station 2. The decrease in benthic densities at the deep station may have been caused by bottom scour due to the mechanical destratification, combined with fish predation.

Macrophytes. The areal extent of macrophytes harvested and left in place in the lake during the 1985 season is shown in figure 13. Approximately 10 of the 15.4 acres of weed bed, composed predominantly of *Potomogeton crisous* (curly leaf pondweed), were harvested in June 1984 and again in 1985. The harvested area remained free of regrowth of nuisance proportions for the remainder of the recreational season. The harvesting and removal of macrophytes improved the aesthetics of the lake and enhanced the recreational aspects such as fishing and boating in the shallow end of the lake. It is estimated that a total of 172 tons (wet weight) of macrophytes was harvested and removed from the lake each year. This represents an export of about 125 pounds of total phosphorus from the lake and approximately 31% of the gross pre-lake management phosphorus loading to the lake.

Fisheries. An assessment of the fisheries resources in Johnson Sauk Trail Lake during 1985 made by Alec Pulley, district fisheries manager, Illinois Department of Conservation, is given below:

> Largemouth bass established an extremely weak year class in 1985. This year class and the weak 1984 year class are the poorest in the lake's 20-year history. The dominant 1983 year class collected at a rate of 27

Table 8. Benthic Macroinvertebrates Collected from Johnson Sauk Trail Lake (Individuals per square meter and % of total)

	1981							
	6/9		7/7		8/4		9/1	
	No.	%	No.	%	No.	%	No.	%
Station 1								
Ceratopogonidae (biting midge)								
Chaoborus (phantom midge fly)	21%	52	1091	31	7320	86	8913	98
Chironomidae (midge fly)	2052	48	2454	69	1220	14	144	2
Total	4248	100	3545	100	8540	100	9057	100
Station 2								
Ceratopogonidae (biting Midge)	43	7			14	0		
Chaoborus (phantom midge fly)	158	24	301	46	7 894	92	2354	89
Chironomidae (midge fly)	316	48	14	2	402	5	43	2
Sphaerium (fingernail clam)	14	2						
Tubificidae (sludge worm)	129	19	345	52	301	3	230	9
Total	660	100	660	100	8611	100	2627	100

	1985							
	6/10		7/8		8/5		9/3	
	No.	%	No.	%	No.	%	No.	%
Station 1								
Ceratopogonidae (biting midge)	14	2	14	4	43	4		
Chaoborus (phantom midge fly)	603	81	129	39				
Chironomidae (midge fly)	129	17	187	57	990	96	43	100
Total	746	100	330	100	1033	100	43	100
Station 2								
Ceratopogonidae (biting Midge)			201	25	43	5	2 87	3 9
Chaoborus (phantom midge fly)	172	92	43	5	57	6	86	23
Chironomidae (midge fly)	14	8	560	70	804	89	359	49
Sphaerium (fingernail clam)								
Tubificidae (sludge worm)								
Total	186	100	804	100	904	100	732	100

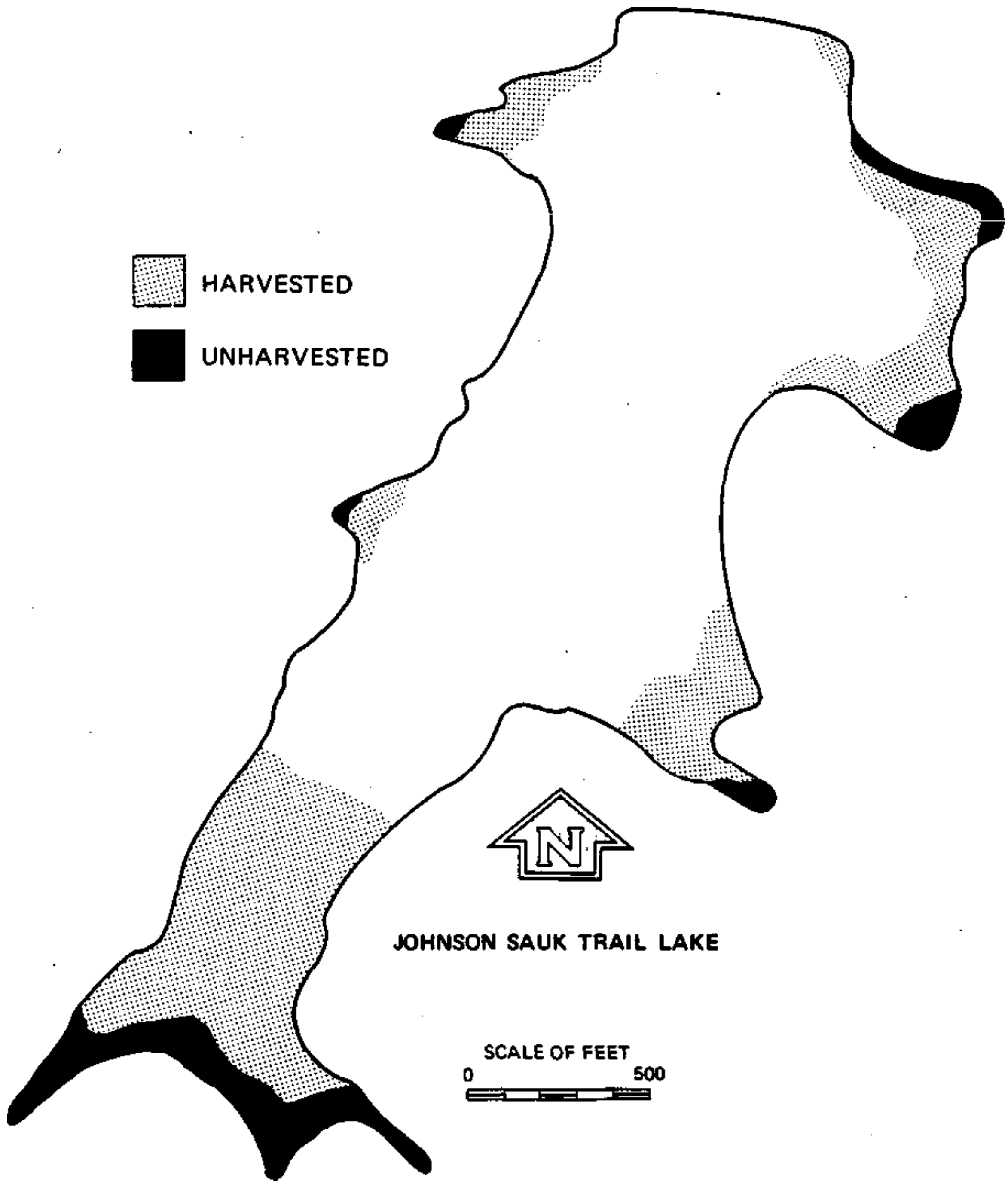

Figure 13. Areal extent of harvested and unharvested macrophytes in Johnson Sauk Trail Lake during 1985

f/hour by electrofishing apparently suppressed both of these year classes. The 1982 year class (11.4 f/hour) and the 1981 year class (7.9 f/hour) combined with the 1983 year class comprised 91% of the bass sample. The mortality rates of 26%, 54% and 63% (1983 to 1981 yc) reflect increased angler harvest. With a decline in overall bass abundance, the relative weights and growth rates have not increased as expected. 1986 should be a year of increased bass growth and year class success.

The blueoill population is in a balanced state in relation to other fishes and its own food supply. This occurs in spite of fairly large year classes formed in 1984 and 1985. Both groups are growing below the state average but well within the normal rate for this lake. Growth was excellent for bluegill ages 2 to 4, and the relative weights have improved from 1 year ago as follows:

PERCENT AVERAGE WT. OF BLUEGILL COMPARED TO
STANDARD WEIGHT BY YEAR CLASS

	1984	1985
AGE I	94	97
AGE II	92	100
AGE III	96	106
AGE IV	83	97

Fishing pressure was heavy in 1985 and many bluegill were removed from the lake.

The harvest of larger redear sunfish was heavy in 1985 and reproduction has declined in the past 2 years. As bluegill increase in number redear will continue to decline. Crapoie are rarely collected beyond Age II due to angler harvest. Reproduction occurs annually but large, dominant year classes have not occurred for many years. Northern pike and muskie were not collected in 1985. No increase or decrease is seen of black or vellow bullhead. carp or golden shiners compared to former years. Catfish are stocked annually. Brook silversides were collected only in the spring. A large population was formed in 1984, but apparently did not survive through 1985.

Lake Trophic Status. The index system developed by Carlson (1977) for secchi disc transparencies was used to evaluate the trophic status of the lake. The numerical index ranges from 0 to 100. Lakes with trophic state index (TSI) values less than 40 are classified as oligotrophic (nutrient-poor, or relatively unproductive, biologically speaking), and those with TSI values greater than 50 are classified as eutrophic (highly productive). Each major division C10, 20, 30, etc.) represents a doubling of algal biomass.

The TSI values not only assist in evaluating the trophic condition of a lake but also permit an assessment of the changes in a lake after implementation of a management scheme to improve its overall quality.

The TSi vaiues for Johnson Sauk Trail Lake ranged from 46.2 to 87.1 with a mean of 59.6 (n = 17) for the pre-management period (January to December 1981). The TSI values were found to vary from 45.6 to 71.3 with a mean of 60.3 (n = 17) for the post-management period (October 1984 - September 1985). The lake continues to be eutrophic and there is practically no change in the mean TSI after implementation of the management scheme. It may take a few years of continued and uninterrupted lake management before any perceptible change in the lake's trophic state can be observed.

STATISTICAL ANALYSES

The dissolved oxygen, physical, and chemical data for station 1 were used in a statistical analysis to test the hypothesis that the means of observed data for the pre-project period and the means of observed data after implementation of the lake management strategies are the same. The "Student t test" was used to test this null hypothesis.

The data for dissolved oxygen were treated in four groups. Group A dealt with all the data collected in 1981 plus the data from May 1984 through August 1984 versus the data collected from September 1984 through September 1985. Group B dealt with the critical summer months of June through August 1981 versus June through August 1985. Group C consisted of June through August of both 1981 and 1984 versus June through August of 1985. Group 0 dealt with data collected from May through September of 1981 and 1985.

The results of the statistical analyses of dissolved oxygen data for different depths at station 1 are shown in table 9. The computed 't' values and the degrees of freedom are shown in the tables. The critical 't' values at a level of significance of 0.05 can be obtained from any statistical textbook. From the results shown in table 9, it is seen that the computed 't' values are less than the critical values for depths up to 10 feet from the surface. Consequently, the null hypothesis cannot be rejected for these depths. That is, the mean dissolved oxygen values of the data for the two time periods considered are statistically similar. However the computed 't' values are much higher than the critical 't' values for depths of 12 feet and below (except for the near-bottom values), leading to the

Table 9. Student "t" Statistics for Dissolved Oxygen

Depth (feet)	Data Set A	Data Set B	Data Set C	Data Set D
	t/df	t/df	t/df	t/df
0	0.715/44	1.064/10	1.069/18	0.853/18
2	0.490/44	0.983/10	0.840/18	0.844/18
4	0.125/44	1.078/10	0.635/18	0.855/18
6	0.446/44	1.041/10	0.127/18	0.755/18
8	0.305/44	0.933/10	1.092/18	1.226/18
10	0.915/43	1.421/10	1.483/18	1.987/18
12	2.744/43*	3.477/10*	2.368/18*	3.366/18*
14	3.437/42*	3.590/10*	4.009/18*	3.364/18*
16	3.330/42*	3.161/10*	3.618/18*	2.882/18*
18	3.541/34*	2.919/ 6*	3.203/14*	2.925/12*
20	1.829/31	27.592/15*	0.756/13	0.050/10

Data Set A: (All of 1981 plus May 1984 through Aug. 1984 vs. Sep. 1984 through Sep. 1985)
B: (June 1981 through Aug. 1981 vs. June 1985 through Aug. 1985)
C: (June 1981 through Aug. 1981 plus June 1984 to Aug. 1984 vs. June 1985 to Aug. 1985)
D: (May 1981 through Sep. 1981 vs. May 1985 through Sep. 1985)
* Significant at 0.05 level

conclusion that these means are not statistically the same. Destratification of the lake resulted in enhanced oxygen conditions in the lake at depths of 12 feet from the surface and beyond except at the very bottom.

The results of statistical tests for the physical and chemical data for the surface, mid-depth, and near-bottom sampling points at station 1 are shown in table 10. Only two groups of data -- groups A and B as defined earlier -- were considered in these analyses.

The means of secchi disc and turbidity observations were not found to be different for the two time periods considered in each of the groups except for the mid-depth group B data for turbidity. The differences in pH values of group A data for the surface and groups A and B data for the near-bottom waters were statistically significant. Alkalinity values for the surface and deep samples were statistically different, but they were not significantly different for mid-depth samples. Conductivity values were similar for all the sampling points in the lake.

The mean values for total phosphorus were significantly different at the 0.05 level for the surface waters and for the

Table 10. Student "t" Statistics for Physical and Chemical Parameters

Parameters	Surface Data Set A	Surface Data Set B	Mid-depth Data Set A	Mid-depth Data Set B	Near Bottom Data Set A	Near Bottom Data Set B
	t/df	t/df	t/df	t/df	t/df	t/df
Secchi	0.221/38	0.054/10				
Turbidity	1.028/37	2.269/ 8	1.270/40	2.313/ 8*	0.031/40	0.983/ 8
pH	2.167/39*	0.913/10	0.148/42	0.487/10	5.183/42*	6.410/10*
Alkalinity	3.392/39*	2.483/10*	1.783/42	2.156/10	2.005/42	3.367/10*
Conductivity	1.027/39	1.174/10	1.144/42	1.012/10	0.218/42	0.339/10
Total phosphate	2.559/39*	4.988/10*	0.595/42	3.170/10*	1.756/42	1.850/10
Dissolved phosphate	3.097/39*	2.820/10*	2.699/42*	2.473/10*	1.623/42	1.989/10
Total ammonia	1.457/39	1.193/10	0.669/42	0.663/10	2.644/42*	2.909/10*
Nitrate	0.500/39	0.612/10	0.951/41	1.596/10	1.542/41	1.458/10
Kjeldahl nitrogen	0.544/39	1.253/10	1.011/42	1.440/10	0.797/41	1.089/10
Dissolved solids	0.532/39	0.349/10	0.996/42	0.174/10	2.064/42*	1.494/10
Total suspended solids	2.155/39*	2.559/10*	1.008/42	1.646/10	1.206/42	0.550/10
Volatile suspended solids	0.313/39	1.605/10	0.713/42	0.258/10	2.206/42*	0.907/10

Data set A: (All of 1981 plus May 1984 through Aug. 1984 vs. Sep. 1984 through Sep. 1985)
Data set B: (June 1981 through Aug. 1981 vs. June 1985 through Aug. 1985)

* Significant at 0.05 level

mid-depth group B data. The values for dissolved phosphorus were significantly different for the surface and mid-depth waters. For the near-bottom waters, total and dissolved phosphorus values were not significantly different at the 0.05 level. The differences between the mean values of the pre- and post-management period data for various forms of nitrogen in the lake were not significantly different. The only exception was the mean values for ammonia of the near-bottom water samples.

The mean values for dissolved solids for various periods belong to the same sample population. However, the suspended solids data for the surface sample belong to different sample populations. The mean suspended solids value for the period with total lake mixing was higher than for the period without lake mixing. The differences in mean values for volatile suspended solids were not statistically significant except in the case of the group A data set for the near-bottom waters.

A comparison of water quality standards violations during the pre- and post-project monitoring periods is shown in table 11. A significant improvement in dissolved oxygen conditions after implementation of the lake management scheme is readily apparent. However, total phosphorus conditions in the lake could not be improved with the in-lake management scheme adopted, despite the fact that the lake's watershed is primarily in a natural vegetative state. Because the lake was formed on rich and fertile soil, it is doubtful whether the phosphorus conditions in the lake can be brought under control on a long-term basis to meet the state's standard for phosphorus.

Table 11. Comparison of Water Quality Standards Violations
(Percent of observations with violations occurring)

Parameters	Preproject Period Surface	Preproject Period Mid-depth	Preproject Period Deep	Postproject Period Surface	Postproject Period Mid-depth	Postproject Period Deep
Total dissolved solids	0	0	0	0	0	0
pH	35	12	0	17	17	22
Ammonia-N	0	0	18	0	0	0
Total phosphate-P	59	77	77	7 8	67	83
Dissolved oxygen	0	47	65	11	11	17
Temperature	0	0	0	0	0	0

PUBLIC PERCEPTIONS OF LAKE CONDITIONS

On August 19, 1985, the authors informally questioned a few lake visitors and workers in the lake area regarding their perceptions of the conditions of the lake. This was done primarily to get some idea about the public's perception of the lake conditions before and after implementation of the lake management techniques.

Bob Price, 618 N. Jackson, Kewanee, !L, and Frank Cleaver, 1122 Rockwell, Kewanee, stated that the lake condition had improved and fishing had been much better in the last 1-1/2 years.

Joe Roush of Manlius, IL, who worked at the concession stand, stated that in previous years, cleaning the boat bottoms at the end of the season for winter storage was an unpleasant, smelly job. He did not experience any such problem during the cleaning operation at the end of the 1984 recreation season.

Ed Saey, Johnson Sauk Trail Lake park ranger, indicated that he had heard a lot of positive comments from the public about the lake condition and particularly about the enhanced aesthetic appearance of the lake due to weed harvesting.

The number of visitors to the state park during 1985 was reported to be about 259,002, which is about 32% less than the 379,581 people who visited the park during 1981. The popular annual 2-day "Sauk Trail Rendezvous" event, which formerly attracted 5,000-10,000 visitors, has been discontinued since 1981. However, the park ranger indicated that the park attendance in 1985 was higher than that for 1984 and the other years after 1981 when the special "Rendezvous" event was not held.

SUMMARY

As a result of the detailed diagnostic-feasibility study of Johnson Sauk Trail Lake conducted in 1981 (Kothandaraman and Evans, 1983), several in-lake water quality management techniques were implemented in the lake with funding from USEPA's 314 Clean Lakes Program and from the Illinois Department of Conservation on a 50/50 cost share basis. These techniques included a) aeration/destratification of the lake, b) periodic applications of chelated copper sulfate followed by potassium permanganate applications to control blue-green algae, c) harvesting and removal of macrophytes from selected areas in the lake, and d) lake shore stabilization at three on-shore locations. The primary objectives of the lake management were to enhance the water quality conditions and thereby the aesthetic qualities of the lake and to improve fishing and other recreational opportunities.

A low-energy, mechanical, reversible draft destratifier (developed at Oklahoma State University) with a 2-horsepower motor was installed in 1984. The 2-horsepower motor was replaced with a 3-horsepower motor in 1985. Single point application Cwith the aid of the destratifier) of copper sulfate chelated with citric acid was employed once each in 1984 and 1985 to control blue-green algae. Copper sulfate pentahydrate was used at the rate of 5.4 pounds per acre and citric acid monohydrate was applied at the rate of 2.7 pounds per acre. The chelated copper sulfate application was followed in 24 to 48 hours by an application (again with the aid of the destratifier) of potassium permanganate at the rate of 1.1 pounds per acre. This method of chemical application was found to be effective and economical, requiring minimal manpower. Approximately 10 acres of the 15.4 acres of weed beds were harvested and removed from the lake once in early summer 1984 and again in early summer 1985. Shoreline stabilization was accomplished by placement of riprap in 1984.

The mechanical unit was found to be effective in destratifying the lake, rendering the 00 and temperature nearly uniform throughout the water column in the deepest part of the lake. Presence of adequate levels of oxygen in the otherwise hypolimnetic anoxic zone increased fish habitat to 100% of the lake volume during summer months. Generally, there was no statistical difference in secchi disc transparency and turbidity values between the pre-project and post-project periods.

The trends of the observed lake pH and alkalinity values are probably attributable to whole lake mixing. They may also indicate that algal photosynthesis and decomposition of lake bottom sediments were less in the 1984-1985 period than in 1981.

Even though the lake surface water mean total phosphorus concentration was twice as high during the 1984-1985 period as in 1981, algal densities during summer 1985 were much less than in summer 1981. Also, the species dominance shifted from scum-forming blue-green algae on all visits in 1981 to the more desirable greens and diatoms on 6 of 10 visits in 1985. This resulted in a significant enhancement of lake aesthetic conditions.

Harvesting of macrophytes also improved lake aesthetics and enhanced the recreational aspects such as fishing and boating in the shallow end of the lake. One harvesting in June sufficiently controlled macrophytes for the remainder of the recreational season. Removal of macrophytes from the lake was estimated to result in an export of about 31% of the gross pre-lake management phosphorus loading.

The management scheme implemented for Johnson Sauk Trail Lake improved oxygen conditions in the lake, expanded fish habitat, controlled algal blooms and problem-causing blue-green algae, and greatly enhanced aesthetic conditions in the lake. The general perception of visitors to the state park and those who work in and around the lake environs is that fishing opportunities and lake aesthetic conditions have greatly improved with lake management.

The goal of maintaining a DO concentration of 5 mg/L in the deepest portion of the lake was achieved when the destratifier was in operation with the exception of a brief period in July 1985 when the DO levels were very low throughout the lake. Secchi disc transparencies during summer months were below the desired value of 48 inches. Total phosphorus was less than 0.05 mg/L during spring turnover (March-April). The average annual suspended solids and turbidity values for the lake's surface waters were less than 25 units. All the water quality goals excepting secchi disc transparency were achieved with the management plan adopted for Johnson Sauk Trail Lake.

The in-lake management techniques adopted for Johnson Sauk Trail Lake are generally applicable to other lakes in Illinois with appropriate modifications to suit site conditions. A similar management scheme first instituted in Lake Eureka (Kothandaraman and Evans, 1982) and subsequently adopted for Sparta and Altamont Reservoirs in Illinois improved the water quality conditions in these water supply lakes, thereby mitigating taste and odor problems and reducing water treatment costs.

RECOMMENDATIONS

- Operation of the destratifier should be monitored closely and prompt action taken to correct any problems. If the destratifier is inoperative for any period of time, benefits of the lake management may be negated. The mechanical destratifier is the crux of the lake management scheme; thus, it is essential that the unit be properly maintained and operated for the beneficial effects of lake management to be fully realized.

- The destratifier should be operated in the downflow mode in the summer months except when algicide is being applied. It should be operated in the upflow mode in winter months. The unit has to be operated continuously for about 9 months a year except during the spring and fall turnovers when the lake is naturally well mixed.

- The pitch of the impeller should be adjusted so the downflow draft just grazes the lake bottom when the lake tends to stratify with highest stability. This can be achieved only by a trial and error process involving a scuba diver. Proper setting of the blade pitch will ensure total destratification of the lake, thus eliminating anoxic conditions while minimizing bottom scour.

- The U bolts holding the blades to the hub of the impeller should be inspected periodically (at least once a year) and replaced when necessary. The shaft bearings should be greased periodically.

- Timely application of algicide to control blue-green algae is very important. Chemicals, application rates, and methods should be the same as those used in 1985. Close monitoring of algal bloom conditions in the lake and initiation of appropriate remedial actions will improve aesthetic conditions in the lake. Licensed applicators should be readily available to apply algicide at short notice. Perhaps site personnel could be trained and licensed to do so.

- Monitoring of the lake for dissolved oxygen, temperature, and secchi disc transparencies at biweekly intervals throughout the year is desirable. Also identification and enumeration of phytoplankton at biweekly intervals from May through September is recommended.

- Annual harvesting of macrophytes from the lake is recommended. From an ecological viewpoint, harvesting is more desirable than chemical control. The economic feasibility of purchasing a weed harvesting system (harvester and lake-to-shore conveyor) and using it on a regional basis for harvesting macrophytes in Johnson Sauk Trail Lake and other IDOC lakes should be considered. In any case, weed harvesting should be made more automated and efficient, demanding less park staff manpower. Some effort should be devoted to gathering and removing floating weed fragments left behind the harvester. This is particularly important in the boat dock area. These fragments cause nuisance conditions around the dock area, decompose, and release nutrients readily available to promote algal growth. Blue-green algae blooms became apparent 2-3 weeks after weed harvesting in 1984 and 1985.

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Appendix 1. Dissolved oxygen, temperature observations in Johnson Sauk Trail Lake, Station 1

Depth	5/09/84		5/23/84		6/06/84		6/20/84		7/05/84		7/18/84	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	9.3	13.5	9.7	19.5	10.5	21.6	12.2	26.0	16.6	25.0	6.7	25.5
2	9.3	13.5	9.0	19.3	10.4	21.6	12.2	26.0	15.4	24.4	5.2	25.0
4	9.3	13.5	8.9	19.0	10.3	21.6	10.1	26.0	12.0	24.0	4.1	25.0
6	9.1	13.1	8.6	19.0	9.4	21.6	8.2	25.0	5.1	23.5	3.3	25.0
8	9.0	13.0	8.4	19.0	9.4	21.6	5.8	24.5	4.1	23.2	0.9	25.0
10	8.9	13.0	8.1	18.8	9.4	21.6	3.1	23.5	3.6	23.1	0.8	24.5
12	8.9	13.0	5.8	17.8	9.4	21.6	1.5	22.2	2.4	23.0	0.7	23.0
14	8.4	13.0	2.9	16.5	1.7	15.6	1.1	20.5	0.5	22.2	0.7	22.0
16	6.0	12.5	1.3	14.9	1.4	14.2	1.1	17.0	0.5	21.5	0.7	21.0
18	3.9	12.0	0.7	13.2	1.2	13.9	1.1	15.5	0.5	21.0	0.6	20.0
20	1.7	11.9	--	--	1.5	14.0	1.1	14.0	0.5	21.0	0.5	18.5
22	--	--	--	--	1.1	13.5	--	--	--	--	--	--

Depth	7/25/84		8/01/84		8/10/84		8/22/84		9/05/84		9/19/84	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	4.6	26.2	14.4	26.0	4.2	28.0	5.3	25.8	3.6	22.0	8.9	19.6
2	4.5	26.2	14.3	26.0	4.1	28.0	3.8	25.2	3.5	22.0	8.5	19.2
4	4.5	26.2	11.4	25.5	3.5	27.5	3.6	25.0	3.5	22.0	8.1	18.9
6	4.2	26.2	10.4	25.2	2.4	27.5	2.8	25.0	3.5	22.0	7.8	18.9
8	3.7	26.1	10.0	25.2	2.4	27.5	2.8	24.9	3.5	22.0	7.6	18.9
10	3.6	26.1	9.2	25.0	1.7	27.5	2.8	24.9	3.5	22.0	7.6	18.9
12	3.6	28.1	8.2	25.0	1.1	27.0	2.6	24.9	3.5	22.0	7.6	18.9
14	3.3	26.1	5.2	24.4	0.7	27.0	2.2	24.9	3.5	22.0	7.6	18.9
16	2.9	26.1	5.2	24.4	0.7	26.0	2.2	24.8	3.5	22.0	7.5	18.9
18	2.7	26.1	3.9	24.2	0.7	26.0	0.7	24.6	3.5	22.0	7.3	18.8
20	2.1	26.1	2.7	24.2	0.7	26.0	0.6	23.6	2.7	22.0	4.4	18.7
22	0.7	25.5	2.0	24.1	0.7	25.0	--	--	--	--	--	--

Appendix 1. Dissolved oxygen, temperature observations in Johnson Sauk Trail Lake, Station 1

Depth	10/17/84		11/15/84		12/12/84		1/22/85		2/15/85		3/13/85	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	6.3	16.0	11.2	6.5	12.0	3.5	11.5	1.0	11.5	1.0	11.5	2.8
2	6.2	16.0	11.2	6.5	12.0	3.5	11.5	1.5	11.5	1.0	11.4	2.8
4	6.2	16.0	11.2	6.5	12.0	3.5	11.5	1.5	11.5	1.0	11.4	2.8
6	6.2	16.0	11.2	6.5	12.0	3.5	10.6	1.5	11.5	1.0	11.4	2.8
8	6.2	16.0	11.2	6.5	12.0	3.5	5.2	1.5	11.5	1.0	11.4	2.8
10	6.2	16.0	11.2	6.5	12.0	3.5	—	—	11.5	1.0	11.4	2.8
12	6.2	16.0	11.2	6.5	12.0	3.5	—	—	9.2	1.0	11.3	2.8
14	5.9	16.0	11.2	6.5	12.0	3.5	—	—	—	—	11.2	2.7
16	5.9	16.0	11.2	6.5	12.0	3.5	—	—	—	—	11.2	2.7
18	5.9	16.0	—	—	12.0	3.5	—	—	—	—	11.2	2.7
20	5.6	16.0	—	—	1.3	3.5	—	—	—	—	10.8	2.7

Depth	4/16/85		5/13/85		5/28/85		6/10/85		6/24/85		7/08/85	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	13.6	13.8	8.5	19.5	8.7	19.9	6.7	23.0	13.5	23.5	9.9	25.5
2	13.1	13.7	8.3	19.5	8.4	19.9	6.6	23.0	14.2	23.5	9.7	25.5
4	13.3	13.3	8.3	19.5	8.4	19.9	6.5	23.0	13.0	23.0	9.6	25.5
6	13.3	13.0	8.3	19.5	8.4	19.8	5.3	22.5	12.2	22.5	9.5	25.5
8	13.3	13.0	8.3	19.5	8.4	19.8	5.2	22.5	11.8	22.5	9.6	25.5
10	13.2	12.6	8.3	19.5	8.4	19.8	4.5	22.5	11.2	22.5	9.6	25.5
12	13.0	12.4	8.3	19.5	8.3	19.8	2.7	22.0	11.2	22.5	9.5	25.5
14	12.9	12.1	8.3	19.5	8.2	19.7	2.1	22.0	10.6	—	9.5	25.5
16	12.0	11.2	8.1	19.5	8.5	19.5	0.5	21.5	10.6	—	9.5	25.5
18	10.3	10.2	8.1	19.2	7.8	19.5	—	—	—	—	8.5	25.5
20	9.1	9.9	—	—	0.5	19.4	—	—	—	—	—	—

Appendix 1. Dissolved oxygen, temperature observations in Johnson Sauk Trail Lake, Station 1

Depth	7/22/85		8/05/85		8/19/85		9/03/85		9/18/85	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	1.9	26.0	7.7	23.5	4.1	25.2	7.7	24.5	8.9	20.0
2	1.6	26.0	7.7	23.5	4.2	25.2	7.6	24.5	8.9	20.0
4	1.5	26.0	7.4	23.5	4.2	25.2	7.6	24.5	8.9	20.9
6	1.5	26.0	7.4	23.5	4.2	25.2	7.6	24.5	8.9	19.9
8	1.5	26.0	7.4	23.5	4.2	25.2	7.6	24.5	8.9	19.9
10	1.5	26.0	7.2	23.5	4.2	25.2	7.6	24.5	8.9	19.9
12	1.5	26.0	7.2	23.5	4.2	25.2	7.5	24.5	8.9	19.9
14	1.5	26.0	7.2	23.5	4.2	25.2	7.5	24.5	8.9	19.9
16	1.5	26.0	7.2	23.5	4.2	25.2	0.5	24.5	8.9	19.9
17	--	--	--	--	4.0	25.2	--	--	8.9	19.9
18	1.5	26.0	--	--	--	--	--	--	--	--
20	1.4	26.0	--	--	--	--	--	--	8.9	19.9

Appendix 1. Dissolved oxygen, temperature observations in Johnson Sauk Trail Lake, Station 2

Depth	5/09/84		5/23/84		6/06/84		6/20/84		7/05/84		7/18/84	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	9.1	14.0	8.6	19.8	9.0	21.2	14.1	26.2	16.0	26.0	7.8	26.0
1	9.1	14.0	8.6	19.8	8.9	21.0	14.1	26.0	15.9	24.8	7.8	26.0
2	9.1	14.0	8.6	19.8	8.8	21.0	14.0	26.0	12.0	24.2	7.8	26.0
3	9.1	13.9	8.6	19.8	8.7	21.0	14.0	26.0	12.4	24.2	7.8	26.0
4	9.2	13.9	8.6	19.8	8.9	20.8	14.0	26.0	8.2	24.0	7.8	26.0
5	9.2	13.8	8.6	19.5	8.7	20.2	14.0	25.9	9.9	24.0	7.7	26.0
6	9.2	13.8	8.6	19.5	8.6	20.2	12.6	25.5	8.1	23.9	7.8	26.0
7	9.5	12.5	8.5	18.8	8.4	19.9	11.1	25.0	4.2	23.6	8.1	25.5
8	9.4	12.0	8.5	18.5	7.8	19.6	4.1	24.5	—	--	3.5	25.0
9	9.1	11.5	5.5	18.2	6.3	19.1	4.0	24.5	—	—	--	--
10	--	--	5.2	18.0	5.7	19.0	--	--	—	—	--	--

Depth	7/25/84		8/01/84		8/10/84		8/22/84		9/05/84		9/19/84	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	9.8	26.9	11.8	25.6	4.5	28.0	8.3	26.0	5.1	22.0	8.5	19.0
1	9.0	26.8	10.2	25.5	4.3	28.0	8.0	26.0	5.0	22.0	8.4	18.9
2	7.8	26.8	9.4	25.0	4.3	28.0	8.0	25.9	5.0	22.0	8.4	18.8
3	6.4	26.6	9.5	24.7	4.4	28.0	4.3	25.2	4.8	22.0	8.3	18.4
4	6.0	26.6	9.4	24.8	4.4	28.0	4.1	25.0	4.8	22.0	8.0	18.2
5	5.8	26.6	9.2	24.7	4.4	28.0	4.0	25.0	4.8	22.0	7.9	18.1
6	5.8	26.5	9.1	24.6	4.4	28.0	3.6	24.9	4.6	22.0	7.4	18.0
7	4.6	26.4	8.9	24.6	3.8	28.0	3.5	24.9	4.3	21.5	7.4	17.8
8	3.5	26.2	8.9	24.4	4.3	28.0	2.9	24.4	4.1	21.5	5.9	17.5
9	--	--	--	--	--	--	--	--	2.8	21.0	5.8	17.2

Appendix 1. Dissolved oxygen, temperature observations in John son Sauk Trail Lake, Station 2

Depth	10/17/84		11/15/84		12/12/84		1/22/85		2/15/85		3/13/85	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	6.9	16.0	11.2	6.5	—	—	10.8	1.0	12.1	0.0	11.8	2.8
1	6.8	16.0	11.0	6.5	—	—	10.4	1.5	11.9	1.0	11.5	2.8
2	6.8	16.0	11.0	6.5	—	—	10.4	1.5	11.2	1.0	11.5	2.8
3	6.8	16.0	11.0	6.5	—	—	10.2	1.8	11.1	1.0	11.4	2.8
4	6.8	16.0	11.0	6.5	—	—	10.0	1.9	11.1	1.5	11.4	2.8
5	6.8	15.5	11.0	6.5	—	—	10.0	2.0	11.1	1.5	11.3	2.8
6	6.8	15.0	11.0	6.5	—	—	10.0	2.0	11.1	1.5	11.3	2.8
7	6.8	15.0	11.0	6.5	—	—	10.0	2.0	11.0	1.5	11.2	2.8
8	3.4	15.0	11.0	6.5	—	—	10.0	2.0	11.0	1.5	11.2	2.8
9	—	—	1.5	6.5	—	—	10.0	2.0	11.0	1.5	11.2	2.8
10	—	—	—	—	—	—	—	—	—	—	9.4	2.8

Depth	4/16/85		5/13/85		5/28/85		6/10/85		6/24/85		7/08/85	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	13.8	14.3	10.2	19.5	10.4	20.2	7.5	24.5	16.9	23.5	11.9	26.0
1	13.8	14.3	9.6	19.5	10.2	20.2	7.4	24.0	15.8	23.5	11.5	26.0
2	13.8	14.3	9.2	19.5	10.2	20.2	7.2	23.0	15.8	23.5	11.5	26.0
3	13.8	14.2	9.2	19.5	10.2	20.2	7.1	23.0	16.6	23.5	9.2	25.5
4	13.8	14.2	9.2	19.5	10.2	20.2	7.1	23.0	14.6	23.5	8.8	25.5
5	13.8	14.1	9.2	19.5	10.2	20.2	7.0	23.0	14.6	22.0	8.2	25.0
6	13.8	14.0	9.2	19.5	10.2	20.2	5.9	22.5	14.0	—	7.5	25.0
7	13.8	13.8	9.1	19.5	9.4	19.2	5.8	22.5	12.1	—	6.2	24.5
8	14.2	13.8	9.1	19.5	8.8	19.0	4.9	22.0	—	—	6.2	24.5
9	14.1	13.8	8.9	19.5	8.0	19.0	4.4	22.0	—	—	4.2	24.0
10	—	—	—	—	8.0	19.0	4.1	22.0	—	—	—	—

Appendix 1. Dissolved oxygen, temperature observations in Johnson Sauk Trail Lake, Station 2

Depth	7/22/85		8/05/85		8/19/85		9/03/85		9/18/85	
feet	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.	D.O.	Temp.
0	2.6	26.5	6.3	23.5	5.2	25.0	6.7	24.0	8.7	20.0
1	2.5	26.5	6.3	23.5	5.0	25.0	6.6	24.0	8.6	20.0
2	2.5	26.5	6.3	23.5	4.9	25.0	6.6	24.0	8.6	20.0
3	2.5	26.5	6.2	23.5	4.9	25.0	6.5	24.0	8.6	20.0
4	2.3	26.5	6.0	23.5	4.9	25.0	5.8	24.8	8.6	19.9
5	2.3	26.5	5.7	23.5	5.0	25.0	5.6	23.8	8.2	19.8
6	2.2	26.0	5.5	23.5	4.7	25.0	4.1	23.8	8.0	19.6
7	2.0	26.0	4.9	23.0	3.9	25.0	4.1	23.8	7.9	19.5
8	2.2	26.0	4.2	23.0	—	—	—	—	7.9	19.5
9	—	—	3.5	23.0	--	--	--	--	--	--

Appendix 2. Physical and chemical quality characteristics of surface waters at station 1 in Johnson Sauk Trail Lake

Parameters	5/09/84	5/23/84	6/06/84	6/20/84	7/05/84	7/18/84
Secchi disc readings (inches)	43.00	60.00	45.00	47.00	27.00	32.00
Turbidity (NTU)	11.00	6.00	20.00	17.00	16.00	13.00
pH (dimensionless)	8.30	8.60	8.70	8.90	9.40	9.00
Alkalinity	172.00	188.00	180.00	178.00	156.00	150.00
Conductivity (umho/cm)	424.00	397.00	392.00	362.00	336.00	333.00
Total phosphate - P	0.03	0.05	0.05	0.03	0.12	0.13
Dissolved phosphate - P	0.00	0.02	0.02	0.01	0.04	0.04
Total ammonia - N	0.04	0.04	0.07	0.10	0.06	0.19
Nitrate - N	0.00	0.19	0.17	0.07	0.06	0.06
Kjeldahl - N,	0.51	0.86	3.16	1.53	2.86	———
Dissolved solids	251.00	293.00	246.00	248.00	232.00	224.00
Total suspended solids	4.00	5.00	11.00	5.00	22.00	10.00
Volatile suspended solids	2.00	5.00	6.00	5.00	18.00	6.00

Parameters	8/01/84	8/22/84	9/05/84	9/19/84	10/17/84	11/15/84
Secchi disc readings (inches)	15.00	31.00	24.00	21.00	30.00	39.00
Turbidity (NTU)	57.00	14.00	24.00	27.00	16.00	11.00
pH (dimensionless)	9.30	8.70	8.50	8.60	8.50	8.20
Alkalinity	160.00	176.00	182.00	180.00	168.00	182.00
Conductivity (umho/cm)	300.00	418.00	312.00	313.00	322.00	324.00
Total phosphate - P	0.28	0.23	0.27	0.21	0.17	0.07
Dissolved phosphate - P	0.10	0.12	0.16	0.10	0.10	0.03
Total ammonia - N	0.14	0.12	0.56	0.44	0.35	0.16
Nitrate - N	0.12	0.05	0.08	0.17	0.05	0.17
Kjeldahl - N	3.20	2.37	1.79	2.02	0.99	1.32
Dissolved solids	220.00	245.00	248.00	246.00	246.00	248.00
Total suspended solids	33.00	8.00	17.00	33.00	10.00	4.00
Volatile suspended solids	33.00	8.00	16.00	12.00	7.00	4.00

Note: Values in mg/l unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of surface waters at station 1 in Johnson Sauk Trail Lake

Parameters	12/12/84	1/16/85	1/22/85	2/15/85	3/13/85	4/16/85
Secchi disc readings (inches)	61.00		72.00	72.00	26.00	107.00
Turbidity (NTU)	5.00	8.00	4.00	7.00	19.00	4.00
pH (dimensionless)	8.30	8.20	8.10	8.00	8.30	8.50
Alkalinity	175.00	174.00	194.00	211.00	172.00	177.00
Conductivity (umho/cm)	348.00	367.00	357.00	400.00	319.00	325.00
Total phosphate - P	0.07	0.07	0.05	0.03	0.02	0.02
Dissolved phosphate - P	0.02	0.02	0.02	0.01	0.02	0.01
Total ammonia - N	0.09	0.05	0.06	0.16	0.09	0.17
Nitrate - N	0.01	0.40	0.02	0.13	0.34	0.03
Kjeldahl - N	1.19	0.75	0.86	1.08	1.13	0.62
Dissolved solids	250.00	394.00	263.00	296.00	230.00	252.00
Total suspended solids	2.00	24.00	4.00	11.00	13.00	1.00
Volatile suspended solids	2.00	3.00	3.00	8.00	7.00	0.00

Parameters	5/13/85	5/28/85	6/10/85	6/24/85	7/08/85	7/22/85
Secchi disc readings (inches)	54.00	27.00	72.00	25.00	18.00	36.00
Turbidity (NTU)	7.00	14.00	5.00	23.00	30.00	11.00
pH (dimensionless)	8.80	8.90	9.00	9.40	9.30	8.70
Alkalinity	156.00	160.00	160.00	162.00	168.00	175.00
Conductivity (umho/cm)	294.00	284.00	301.00	285.00	358.00	386.00
Total phosphate - P	0.08	0.08	0.12	0.16	0.26	0.29
Dissolved phosphate - P	0.03	0.02	0.07	0.04	0.15	0.20
Total ammonia - N	0.06	0.07	0.09	0.10	0.13	0.80
Nitrate - N	0.04	0.05	0.06	0.00	0.09	0.02
Kjeldahl - N	0.16	0.58	0.88	1.83	2.14	2.28
Dissolved solids	110.00	225.00	244.00	238.00	240.00	252.00
Total suspended solids	11.00	17.00	10.00	21.00	28.00	84.00
Volatile suspended solids	7.00	4.00	8.00	16.00	16.00	6.00

Note: Values in mg/l unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of surface waters at station 1 in Johnson Sauk Trail Lake

Parameters	8/05/85	8/19/85	9/03/85	9/18/85
Secchi disc readings (inches)	20.00	32.00	30.00	28.00
Turbidity (NTU)	18.00	12.00	16.00	23.00
pH (dimensionless)	9.10	8.60	9.00	8.90
Alkalinity	179.00	186.00	190.00	191.00
Conductivity (µmho/cm)	375.00	391.00	380.00	395.00
Total phosphate - P	0.25	0.32	0.23	0.20
Dissolved phosphate - P	0.11	0.23	0.14	0.12
Total ammonia - N	0.24	0.64	0.11	0.20
Nitrate - N	0.06	0.07	0.07	0.08
Kjeldahl - N	1.68	1.60	2.09	1.30
Dissolved solids	256.00	272.00	268.00	264.00
Total suspended solids	29.00	18.00	13.00	18.00
Volatile suspended solids	19.00	11.00	12.00	7.00

Note: Values in mg/l unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of mid-depth waters at station 1 in Johnson Sauk Trail Lake

Parameters	5/09/84	5/23/84	6/06/84	6/20/84	7/05/84	7/18/84
Secchi disc readings (inches)	----	----	----	----	----	----
Turbidity (NTU)	12.00	11.00	16.00	10.00	6.00	12.00
pH (dimensionless)	8.30	8.50	8.70	8.50	8.70	8.50
Alkalinity	181.00	196.00	180.00	170.00	168.00	160.00
Conductivity (μmho/cm)	424.00	393.00	394.00	378.00	362.00	352.00
Total phosphate - P	0.03	0.05	0.05	0.04	0.15	0.24
Dissolved phosphate - P	0.00	0.02	0.02	0.01	0.08	0.11
Total ammonia - N	0.04	0.06	0.07	0.15	0.27	0.43
Nitrate - N	0.00	0.18	0.23	0.36	0.05	0.05
Kjeldahl - N	0.55	0.90	2.28	1.42	1.64	———
Dissolved solids	249.00	299.00	244.00	256.00	240.00	240.00
Total suspended solids	7.00	6.00	8.00	0.00	10.00	10.00
Volatile suspended solids	3.00	6.00	4.00	0.00	4.00	5.00

Parameters	8/01/84	8/22/84	9/05/84	9/19/84	10/17/84	11/15/84
Secchi disc readings (inches)	----	----	----	----	----	----
Turbidity (NTU)	43.00	16.00	24.00	27.00	25.00	12.00
pH (dimensionless)	9.00	8.70	8.50	8.50	8.30	8.20
Alkalinity	164.00	168.00	182.00	184.00	168.00	182.00
Conductivity (pmho/cm)	321.00	435.00	306.00	319.00	322.00	322.00
Total phosphate - P	0.95	0.22	0.28	0.22	0.19	0.09
Dissolved phosphate - P	0.11	0.14	0.19	0.10	0.11	0.04
Total ammonia - N	0.06	0.42	0.54	0.45	0.27	0.16
Nitrate - N	0.11	0.01	0.05	0.02	0.03	0.17
Kjeldahl - N	2.02	1.60	1.85	2.11	0.74	0.97
Dissolved solids	218.00	246.00	248.00	244.00	246.00	,246.00
Total suspended solids	20.00	8.00	17.00	37.00	15.00	6.00
Volatile suspended solids	15.00	8.00	14.00	14.00	7.00	3.00

Note: Values in mg/l unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of mid-depth waters at station 1 in Johnson Sauk Trail Lake

Parameters	12/12/84	1/16/85	1/22/85	2/15/85	3/13/85	4/16/85
Secchi disc readings (inches)	----	----	----	----	----	----
Turbidity (NTU)	5.00		6.00	3.00	20.00	5.00
pH (dimensionless)	8.30		8.10	8.00	8.30	8.50
Alkalinity	176.00		194.00	208.00	173.00	178.00
Conductivity (µmho/cm)	349.00		352.00	404.00	320.00.	325.00
Total phosphate - P	0.05		0.06	0.04	0.06	0.02
Dissolved phosphate - P	0.01		0.02	0.02	0.02	0.01
Total ammonia - N	0.10		0.05	0.22	0.03	0.33
Nitrate - N	0.01		0.02	0.11	0.34	0.03
Kjeldahl - N	1.05		0.74	0.90	0.74	0.64
Dissolved solids	250.00		265.00	302.00	230.00	256.00
Total suspended solids	3.00		13.00	8.00	11.00	6.00
Volatile suspended solids	3.00		10.00	4.00	7.00	1.00

Parameters	5/13/85	5/28/85	6/10/85	6/24/85	7/08/85	7/22/85
Secchi disc readings (inches)	----	----	----	----	----	----
Turbidity (NTU)	7.00	14.00	6.00	24.00	28.00	14.00
pH (dimensionless)	8.80	8.70	9.00	9.40	9.10	8.70
Alkalinity	156.00	160.00	162.00	164.00	162.00	175.00
Conductivity (umho/cm)	287.00	282.00	298.00	285.00	357.00	384.00
Total phosphate - P	0.07	0.08	0.12	0.19	0.28	0.31
Dissolved phosphate - P	0.031	0.02	0.08	0.05	0.15	0.22
Total ammonia - N	0.07	0.08	0.12	0.16	0.10	0.83
Nitrate - N	0.04	0.05	0.07	0.00	0.05	0.00
Kjeldahl - N	0.17	0.86	0.78	2.29	2.36	2.22
Dissolved solids	110.00	223.00	242.00	240.00	240.00	246.00
Total suspended solids	8.00	16.00	8.00	24.00	30.00	10.00
Volatile suspended solids	4.00	3.00	6.00	10.00	16.00	6.00

Note: Values in mg/l unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of mid-depth waters at station 1 in Johnson Sauk Trail Lake

Parameters	8/05/85	8/19/85	9/03/85	9/18/85
Secchi di6C readings (inches)	—	—	—	—
Turbidity (NTU)	18.00	12.00	17.00	20.00
pH (dimensionless)	9.10	8.60	9.10	8.90
Alkalinity	179.00	186.00	190.00	191.00
Conductivity (umho/cm)	377.00	389.00	381.00	398.00
Total phosphate - P	0.27	0.31	0.22	0.20
Dissolved phosphate - P	0.11	0.23	0.15	0.11
Total ammonia - N	0.30	0.61	0.12	0.08
Nitrate - N	0.09	0.08	0.07	0.20
Kjeldahl - N	1.63	3.05	2.26	1.52
Dissolved solids	260.00	268.00	258.00	260.00
Total suspended solids	32.00	18.00	15.00	20.00
Volatile suspended solids	19.00	9.00	12.00	5.00

Note: Values in mg/l unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of bottom waters at station 1 in Johnson Sauk Trail Lake

Parameters	5/09/84	5/23/84	6/06/84	6/20/84	7/05/84	7/18/84
Secchi disc readings (inches)	—	—	—	—	—	—
Turbidity (NTU)	16.00	10.00	22.00	15.00	19.00	7.00
pH (dimensionless)	8.10	8.40	7.50	8.20	8.10	8.20
Alkalinity	208.00	200.00	218.00	192.00	184.00	204.00
Conductivity (umho/cm)	429.00	414.00	454.00	413.00	398.00	412.00
Total phosphate - P	0.04	0.06	0.22	0.01	0.43	0.80
Dissolved phosphate - P	0.00	0.03	0.13	0.00	0.30	0.75
Total ammonia - N	0.04	0.08	0.18	0.45	0.77	2.11
Nitrate - N	0.00	0.18	0.27	0.33	0.05	0.03
Kjeldahl - N	0.85	1.03	2.86	1.50	2.15	—
Dissolved solids	257.00	302.00	272.00	270.00	246.00	272.00
Total suspended solids	12.00	6.00	22.00	10.00	21.00	6.00
Volatile suspended solids	4.00	6.00	7.00	8.00	6.00	2.00

Parameters	8/01/84	8/22/84	9/05/84	9/19/84	10/17/84	11/15/84
Secchi disc readings (inches)	—	—	—	—	—	—
Turbidity (NTU)	68.00	17.00	30.00	43.00	25.00	164.00
pH (dimensionless)	8.70	8.20	8.50	8.50	8.60	8.10
Alkalinity	168.00	198.00	182.00	186.00	170.00	186.00
Conductivity (µmho/cm)	334.00	529.00	317.00	314.00	320.00	321.00
Total phosphate - P	0.62	0.53	0.29	0.25	0.19	0.24
Dissolved phosphate - P	0.14	0.14	0.18	0.01	0.11	0.03
Total ammonia - N	0.19	1.91	0.59	0.53	0.28	0.20
Nitrate - N	0.12	0.02	0.06	0.18	0.03	0.20
Kjeldahl - N	2.10	4.49	2.03	2.11	0.90	2.12
Dissolved solids	212.00	258.00	248.00	246.00	242.00	248.00
Total suspended solids	70.00	16.00	18.00	56.00	11.00	204.00
Volatile suspended solids	15.00	10.00	15.00	16.00	7.00	25.00

Note: Values in mg/l unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of bottom waters at station 1 in Johnson Sauk Trail Lake

Parameters	12/12/84	1/16/85	1/22/85	2/15/85	3/13/85	4/16/85
Secchi disc readings (inches)	----	----	----	----	----	----
Turbidity (NTU)	7 . 0 (	----	0 0	38.00	30.00	10.00
pH (dimensionless)	8 . 3	----	1 0	8.00	8.30	8.30
Alkalinity	1 8 3 . 0	----	. 0 0	210.00	173.00	181.00
Conductivity (umho/cm)	3 9 6 . 0	----	. 0 0	393.00	323.00	333.00
Total phosphate - P	0 . 0	----	0 7	0.13	0.09	0.05
Dissolved phosphate - P	0 . 0	----	0 2	0.02	0.02	0.01
Total ammonia - N	0 . 1	----	0 8	0.19	0.05	0.23
Nitrate - N	0 . 0	----	0 2	0.10	0.34	0.03
Kjeldahl - N	1 . 2	----	9 8	1.89	1.41	1.73
Dissolved solids	2 4 8 . 0	----	. 0 0	304.00	228.00	256.00
Total suspended solids	1 4 . 0	----	. 0 0	91.00	26.00	10.00
Volatile suspended solids						
	13.00	----	8.00	11.00	8.00	1.00

Parameters	5/13/85	5/28/85	6/10/85	6/24/85	7/08/85	7/22/85
Secchi disc readings (inches)	----	----	----	----	----	----
Turbidity (NTU)	8.00	42.00	9.00	23.00	38.00	26.00
pH (dimensionless)	8.80	8.70	8.70	9.40	9.10	8.70
Alkalinity	156.00	160.00	162.00	166.00	162.00	177.00
Conductivity (µmho/cm)	287.00	281.00	302.00	294.00	356.00	386.00
Total phosphate - P	0.07	0.19	0.13	0.19	0.31	0.35
Dissolved phosphate - P	0.03	0.02	0.10	0.06	0.14	0.22
Total ammonia - N	0.04	0.08	0.24	0.14	0.29	0.93
Nitrate - N	0.04	0.04	0.08	0.02	0.03	0.00
Kjeldahl - N	0.23	0.90	0.74	1.96	2.54	2.30
Dissolved solids	110.00	225.00	252.00	240.00	240.00	248.00
Total suspended solids	7.00	80.00	10.00	19.00	42.00	34.00
Volatile suspended solids	3.00	8.00	8.00	14.00	14.00	13.00

Note: Values in mg/l unless otherwise indicated.

Appendix 2. Physical and chemical quality characteristics of bottom waters at station 1 in Johnson Sauk Trail Lake

Parameters	8/05/85	8/19/85	9/03/85	9/18/85
Secchi disc readings (inches)				
Turbidity (NTU)	17.00	15.00	17.00	38.00
pH (dimensionless)	9.10	8.70	9.10	8.90
Alkalinity	179.00	186.00	190.00	191.00
Conductivity (µmho/cm)	377.00	390.00	380.00	393.00
Total phosphate - P	0.26	0.32	0.22	0.23
Dissolved phosphate - P	0.11	0.22	0.15	0.12
Total ammonia - N	0.21	0.59	0.14	0.10
Nitrate - N	0.08	0.10	0.07	0.09
Kjeldahl - N	1.82	2.52	1.90	1.46
Dissolved solids	256.00	264.00	256.00	256.00
Total suspended solids	32.00	27.00	15.00	46.00
Volatile suspended solids	18.00	9.00	13.00	30.00

Note: Values in mg/l unless otherwise indicated.

Appendix 3a. Algae types and densities in Johnson Sauk Trail Lake, 1984
(Densities in counts per milliliter)

Name of Algae	5/9	5/23	6/6	6/20	7/5	7/18	8/1	8/22	9/5	9/19
Blue-greens										
Anabena spiroides		50	370	660	21500	170	250	45		
Anacystis cyanea							105		70	
Aphanizomenon flos-aquae		50	230	340	16850		90			
Oscillatoria chlorina	10	20								
Oscillatoria sp.						60				
Greens										
Chlorella ellipsoidea										
Closteriopsis longissima										220
Colastrium microporum									35	10
Oocystis borgei				50						
Pediastrum duplex						15		75	125	30
Pediastrum *simplex*										
Vlothrix variabilis										
Diatoms										
Asterionella *formosa*	1020	10	30							
Cyclotella meneghiniana										
Cymbella affinis										
Cymbella prostrata				10						
Melosira granulata			65				30			
Synedra ulna		10								
Flagellates										
Ceratium *hixundinella*			5		210		20		10	
Dinobryon sertularia		95	40							
Euglena viridis										
Euglena sp.										
Phacus pleuronectes										
Trachelomonas creba										
Other										
Staurastrum cornutum		5								

Appendix 3b. Algae types and densities in Johnson Sauk Trail Lake, 1985
(Densities in counts per milliliter)

Name of Algae	5/13	5/28	6/10	6/24	7/8	7/22	8/5	8/19	9/3	9/18
Blue-greens										
Anabena spiroides		95	120	1960	80	715				
Anacystis cyanea										
Aphanizomenon flos-aquae				670	80					
Oscillatoria chlorina										
Oscillatoria sp.										
Greens										
Chlorella ellipsoidea							265	130		
Closteriopsis longissima								60	50	
Colastrium microporum			30					10		
Oocystis borgei										
Pediastrum duplex			20					30		10
Pediastrum simplex						50			25	20
Ulothrix variabilis					30					
Diatoms										
Asterionella formosa	340	320	10							
Cyclotella meneghiniana									55	30
Cymbella affinis									30	
Cymbella prostrata										
Melosira granulata	35				40	75	390		65	
Synedra ulna										
Flagellates										
Ceratium hirundinella		20	20				60		10	
Dinobryon sertularia		25								
Euglena viridis	25									
Euglena sp.							15			
Phacus pleuronectes			10							
Trachelomonas creba	15	10	20		10					
Other										
Staurastrum cornutum	15	5				5				

Appendix 3c. Biovolumes of algae in Johnson Sauk Trail Lake, 1984
($\mu m^3 \times 10^6$)

Name of Algae	5/9	5/23	6/6	6/20	7/5	7/18	8/1	8/22	9/5	9/19
Blue-greens										
Anabena spiroidss		0.262	1.938	3.457	112.620	0.890	1.390	0.236		
Anacystis cyanea							0.014		0.010	
Aphanizomenon flos-aquae		0.072	0.033	0.487	24.130		0.129			
Oscillatoria chlorina	0.043	0.086								
Oscillatoria sp.						0.258				
Greens										
Chlorella ellipsoidea										1.989
Closteriopsis longissima										
Colastrium microporum									0.075	
Oocystis borgei				0.075						
Pediastrum duplex						0.016		0.080	0.132	0.032
Pediastrum *simplex*										
Ulothrix variabilis										
Diatoms										
Asterionella formosa	0.404	0.004	0.012							
Cyclotella meneghiniana										
Cymbella affinis										
Cymbella prostrata				0.236						
Melosira granulata			0.441				0.204			
Synedra ulna		0.032								
Flagellates										
Ceratium hirundinella			1.152		48.380	4.610			2.804	
Dlnobryon sertularia		4.029	1.696							
Euglena viridis										
Euglena sp.										
Phacus pleuronectes								0.030		
Trachelomonas creba										
Other										
Staurastrum cornutum		0.102								
Total	0.447	4.587	5.272	4.255	185.130	5.774	1.737	0.346	2.521	2.043

Appendix 3d. Biovolumes of algae in Johnson Sauk Trail Lake, 1985 ($\mu m^3 \times 10^6$)

Name of Algae	5/13	5/28	6/10	6/24	7/8	7/22	8/5	8/19	9/03	9/18
Blue-greens										
Anabena spiroides		0.498	0.629	10.260	0.419	3.745				
Anacystis cyanea										
Aphanizomenon flos-aquae				0.959	0.115					
Oscillatoria chlorina										
Oscillatoria sp.										
Greens										
Chlorella ellipsoidea	0.101							0.050		
Closteriopsis longissima								0.542	0.452	
Colastrium microporum			0.064					0.021		
Oocystis borgei										
Pediastrum duplex			0.021					0.032		0.011
Pediastrum simplex						0.053			0.027	0.021
Ulothrix variabilis					0.088					
Diatoms										
Asterionella formosa	0.135	0.127	0.004							
Cyclotella meneghiniana									0.267	0.146
Cymbella affinis									0.118	
Cymbella prostrata										
Helosira granulata	0.238				0.271	0.509	2.647		0.441	
Synedra ulna										
Flagellates										
Ceratium hirundinella		4.608	4.608				13.824		2.304	
Dinobryon sertularia		1.060								
Euglena viridis	0.284									
Euglena sp.							0.170			
Phacus pleuronectes			1.068							
Trachelomonas creba	0.046	0.031	0.061		0.031					
Other										
Staurastrum cornutum	0.306	0.102			0.102			0.204	0.102	0.102
Total	1.110	6.426	6.455	11.219	0.924	4.409	16.641	0.849	3.711	0.280

Appendix 4. Project budget

Destratifier	
Capital cost	$6,000
Installation	3,247
Maintenance	486
Operation	810
Shoreline Stabilization	
Materials	5,058
Labor	1,065
Algicide Applications	1,000
Weed Harvesting	
1984 contract	4,800
1985 contract	5,200
Monitoring	22,265
IDOC Administration	20,755
IEPA Administration	11,680
Total	82,366
USEPA Clean Lakes Program	36,270
IDOC Share	33,831
ISWS Share	12,265