Contract Report 623

Aeration/Destratification in Lake Evergreen, McLean County, Illinois

by

Raman K. Raman, David L. Hullinger, and Shun Dar Lin

Prepared for the
City of Bloomington

March 1998

Illinois State Water Survey
Chemistry Division
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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Table of Contents

Page

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Background

Lake Evergreen, located in McLean County, was formed in 1971 by damming Six-Mile Creek where it flows northward into the Mackinaw River. The topography of the watershed is characterized by gently rolling uplands with slopes leading to the shoreline, unlike the flat open farmland of the surrounding region. There are no industries in the 25,730-acre watershed, and the village of Hudson, population 1,000, is the only community in the watershed. The predominant land use is row crops (87 percent), and other uses include small grains, pasture, alfalfa, residential development, and the impoundment for water supply and water-based recreation.

When originally created, the lake had a surface area of 754 acres at the spillway level, a maximum depth of 48 feet, a mean of 17 feet, and a storage capacity of 11,345 acre-feet. The lake was formed as a supplemental water supply source for the city of Bloomington in addition to its regular source, Lake Bloomington, and for recreational fishing, sailing, and boating.

McLean County experienced a severe two-year drought beginning in the spring of 1988. Lake water levels declined to well over 30 feet below normal pool levels in both lakes. Consequently, the city planned and developed an additional water supply for emergency use, the Mackinaw River Pumping Pool adjoining Lake Evergreen. The city also completed modifications to the Lake Evergreen dam in 1996, increasing the lake's normal pool elevation from 715 to 720 feet above mean sea level (ft-msl). The modifications increased the surface area to 900 acres and the storage volume to 15,480 acre-feet, an increase of approximately 36 percent (Hanson Engineers, 1989). The mean and maximum depths of the lake after the modifications were 22 and 53 feet, respectively. Table 1 provides the elevation-area-volume relationships for Lake Evergreen.

Water quality in the lakes was also extremely poor during the 1988 drought due to a combination of factors: high temperature, increased retention time due to lack of adequate flow through the lakes, algal blooms, intense anoxic conditions, and the resulting release of by-products of anaerobic decomposition such as iron, manganese, ammonia, hydrogen sulfide, etc. These factors subsequently resulted in finished waters with less than desirable qualities. There were numerous consumer complaints about taste and odor in the city's potable water supplies despite efforts by water treatment personnel to control these problems at the treatment plant.

There was a distinct possibility that the water treatment system's intakes in Lake Bloomington could run dry because of the lake's declining water level during the drought.

Table 1. Elevation-Area-Volume Relationships for Lake Evergreen

Elevation, feet-msl	*Area, acres*	*Volume, acre-feet*
720	900	15,480
715	754	11,345
710	600	7,960
700	340	3,260
690	145	835
680	11	55
670	0	0

Source: Hanson Engineers, Inc., 1989

To guard against this possibility, the city procured ten 30-horsepower, 480-volt, three-phase Dobbs floating pumps with a maximum rated capacity of about 870 gallons per minute (gpm) against a total head of 70 feet for each pump. Because the drought ended before the need for the pumps arose, the pumps remained in their original packing at the treatment plant.

Using destratification as a lake management tool, the Illinois State Water Survey has successfully controlled taste and odor problems in finished waters of Illinois communities with impoundments as raw water sources. Notable examples include Eureka, Palmyra, Altamont, Sparta, and Nashville. The city decided to follow these successful examples and install one of the floating pumps in Lake Bloomington near the water treatment plant intake to destratify the lake and enhance its water quality characteristics.

The Dobbs floating pump tried in Lake Bloomington during 1992 was a low-volume high-lift pump. Concurrent evaluations of physical and chemical water quality characteristics of both Lake Bloomington and Lake Evergreen during 1992 revealed that the dissolved oxygen (DO) and temperature conditions were similar in both lakes even though no destratifier was installed in Lake Evergreen. The floating pump did not break up the temperature gradient in the water column. It was not as effective as the high-volume low-head pumps used in Ohio lakes reported by Symons (1969).

On the recommendation of the Illinois State Water Survey, the city installed two Aspir-Air Aeration Systems during 1996, one in Lake Evergreen and another in Lake Bloomington, close to the water intakes. A similar system was installed and investigated by the Illinois State Water Survey (Kothandaraman et al., 1979) in Lake Catherine in Lake County, with significant improvement in physical, chemical, and biological characteristics.

The primary objective of this investigation was to assess the efficacy of the Aspir-Air Aeration System installed in Lake Evergreen in improving the lake's physical and chemical water quality characteristics.

Acknowledgments

This investigation was supported and partially funded by the city of Bloomington. Mr. George Drye (Director of Engineering and Water), Mr. Surinder Sethi (City Engineer), and Mr. Ron Schultz (Superintendent of Water Treatment) were very supportive of the Water Survey's efforts. Other water treatment personnel who assisted in the installation and maintenance of the destratification system were Messrs. Richard Twait, Greg Montague, Tracy Guenther, Richard Alwood, Chuck Otte, Ron Stanley, and Don Thompson. Mr. Greg Kallevig, also with the city of Bloomington, assisted in developing the specifications for the aeration system and provided information for the lake morphometry and water intake structure. They all facilitated the efforts to carry out various facets of the project in a timely fashion, for which the authors are indebted to them. Any opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect those of the City of Bloomington.

Several Water Survey personnel were helpful during the project. Mr. Tom Hill and Mr. Long Duong assisted in field work. Mr. Jon Rodsater took still and video photographs of the aerator installations. Ms. Christie Ragle assisted in laboratory chemical analyses. Ms. Linda Hascall prepared the illustrations, Ms. Linda Dexter typed the draft and final reports, and Ms. Eva Kingston edited the report.

Materials and Methods

A destratification system developed by Aspir-Air, Inc., based in Newberry Springs, California, was chosen based on the past experience of the Illinois State Water Survey with a similar system in Lake Catherine in Lake County. The system consists of a two-stage submersible pump with a rated capacity of 1200 gallons per minute (gpm) at 50 pounds per square inch (psi) driven by a 40-horsepower, three-phase 460-V, 60-cycle Hitachi electric motor and the Aspir-Air, Inc. destratification unit. Figure 1 depicts the unit. The device operates on the Venturi principle. Discharge from the submersible pump is directed through a constriction created by the primary cone shown in figures 2a and 2b. The increased velocity created at the constriction causes a negative pressure to develop at the throat. Because of the negative pressure, air is drawn from the atmosphere through air hoses attached to the air induction nipples and extending above the water surface (figure 3). A PVC pipe directional nozzle is attached to the discharge end of the Aspir-Air unit. The assembly of the submersible pump and the Aspir-Air unit with the nozzle is mounted on a stainless steel skid with a variable pitch mounting system so that the angle of inclination of the assembly can be varied within limits. Figure 2c shows the completely assembled system, except the air hoses, prior to installation.

A helicopter was used to install the aeration system in the lake near the raw water intake structure (figure 2d). The system rested on the lake bottom at a depth of about 34 feet with the air hoses attached to a buoy anchored by a stainless steel cable (figure 3). The system used in Lake Evergreen is quiet during operation. The only obstruction created on the lake surface is the buoy used to support the free ends of two air hoses. The system was installed in the lake on June 16, 1996. The city was able to procure the system completely installed - including all materials and installation costs - for a total of $55,000 based on an open bid process. The city procured two systems, one for Lake Evergreen and another for Lake Bloomington, effecting some economy of scale. The price included a one-year warranty for all parts and labor.

The aerator operated intermittently until August 29, 1996. It was restarted again on June 18, 1997, and operated continuously through the period of lake sampling and monitoring. Figure 4 shows the time line for destratifier operation. Figure 5 shows the location of the aeration device in the lake along with the sampling sites for lake monitoring and water sample collection.

To evaluate the efficacy of the destratification of Lake Evergreen from the standpoint of improvement in water quality, certain physical and chemical characteristics were assessed on a biweekly basis from May 2, 1996 to October 7, 1996 and again from April 22, 1997 to October 7, 1997. Data collected for Lake Evergreen during 1991 and 1992 served to define the pre-aeration water quality characteristics of the Lake (Raman and Twait, 1994).

In-situ observations were made at all three sampling stations for temperature, dissolved oxygen (DO), and secchi disc readings. An oxygen meter (Yellow Springs Instrument Company, model 58 probe with a 50-foot lead) was used to measure DO and

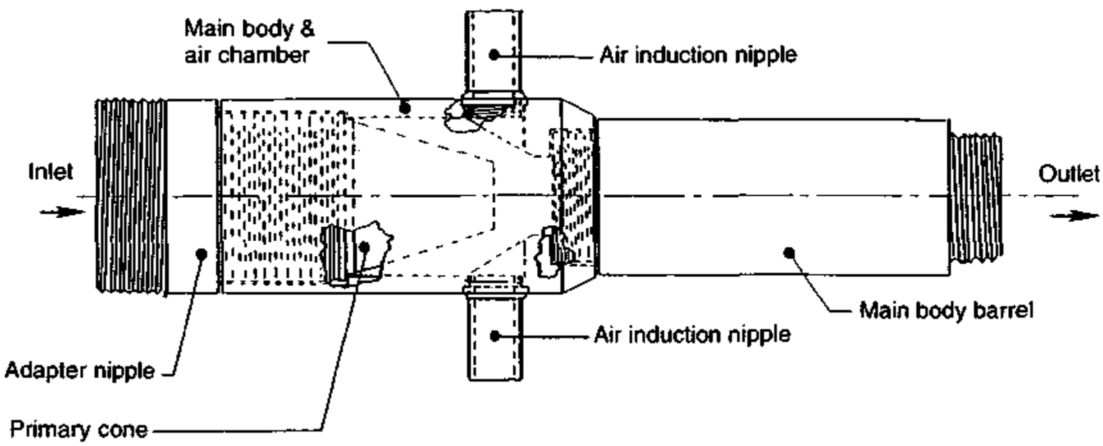
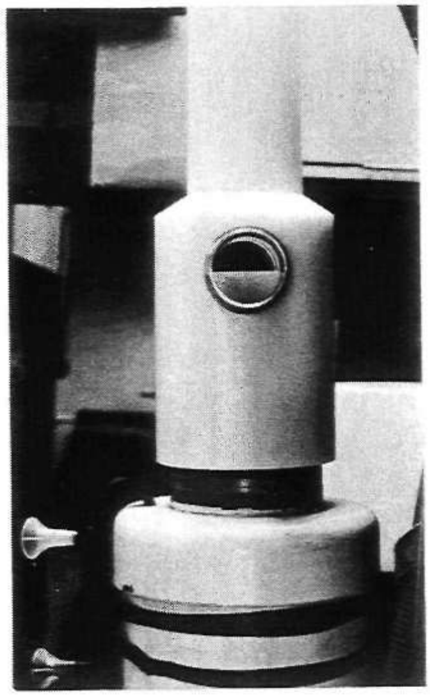
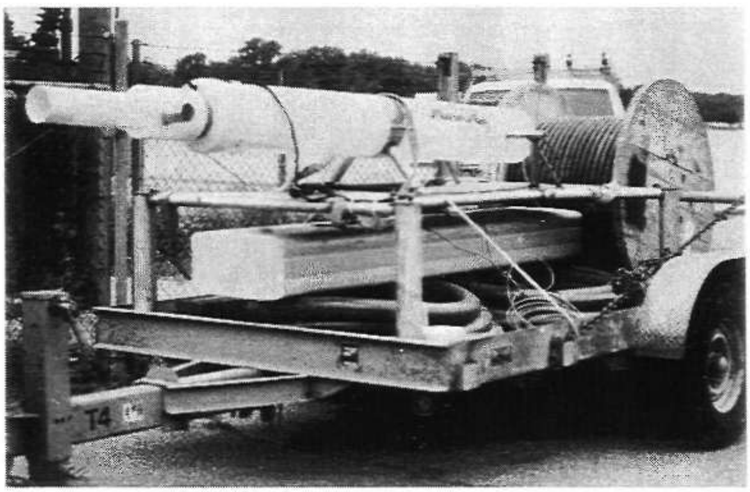


Figure 1. The Aspir-Air, Inc. aeration unit (Kothandaraman et al. 1979)

a. The main barrel, primary cone, and directional nozzle



b. The primary cone shows within the air chamber of the assembled unit



c. The completely assembled system, except air hoses, prior to installation

d. System installation in the lake using a helicopter

Figure 2. The Aspir-Air Aeration System

temperature. The probe was calibrated using a saturation chamber. Temperature and DO measurements were obtained in the water column at 2-foot intervals from the lake surface at stations 1 and 2. Observations were made at 1-foot intervals at station 3.

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

Laboratory determinations included pH, total alkalinity, conductivity, turbidity, dissolved and total phosphate-P, dissolved ammonia-N, nitrate plus nitrite-N, and total dissolved, suspended, and volatile solids. Water samples were collected at a depth of 1 foot from the surface at all stations and at a depth of 2 feet from the bottom using a Kemmerer sampler only at station 2. Samples were collected in plastic bottles, transported to the laboratory in an ice chest, and refrigerated until the analyses were performed. Table 2 presents the methods and procedures used for chemical analyses.

Results and Discussion

Water Quality Characteristics

Physical Characteristics

Temperature and Dissolved Oxygen. Deep lakes in temperate climates generally undergo seasonal variations in temperature through the water column. These variations, with their accompanying phenomena, are perhaps the most influential controlling factors within the lakes.

The temperature of a deep lake in the temperate zone is about 4°C during early spring. As the air temperatures rise, the upper layers of water warm up, and wind action mixes them with the lower layers. By late spring, the differences in thermal resistance cause the mixing to cease, and the lake approaches the thermal stratification of the summer season. Almost as important as water temperature variations is the physical phenomenon of increasing density with decreasing temperature. These two interrelated forces are capable of creating strata of water of vastly differing characteristics within a lake.

During thermal stratification the upper layer (the epilimnion) is isolated from the lower layer of water (the hypolimnion) by a temperature gradient (the thermocline). Temperatures in the epilimnion and hypolimnion are essentially uniform. The thermocline will typically have a sharp temperature drop per unit depth from the upper to the lower

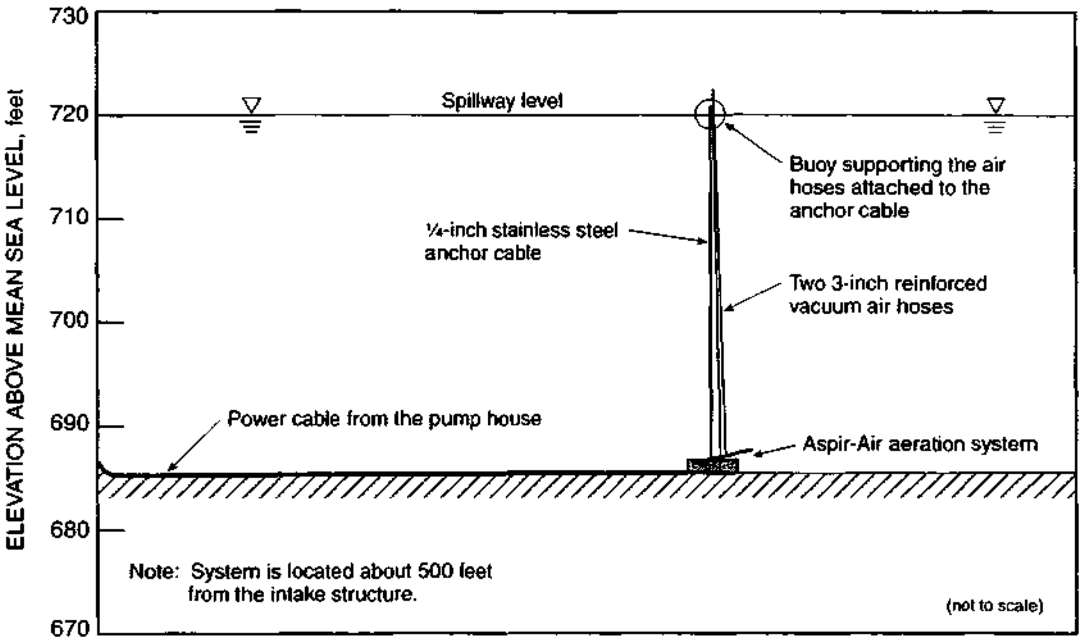
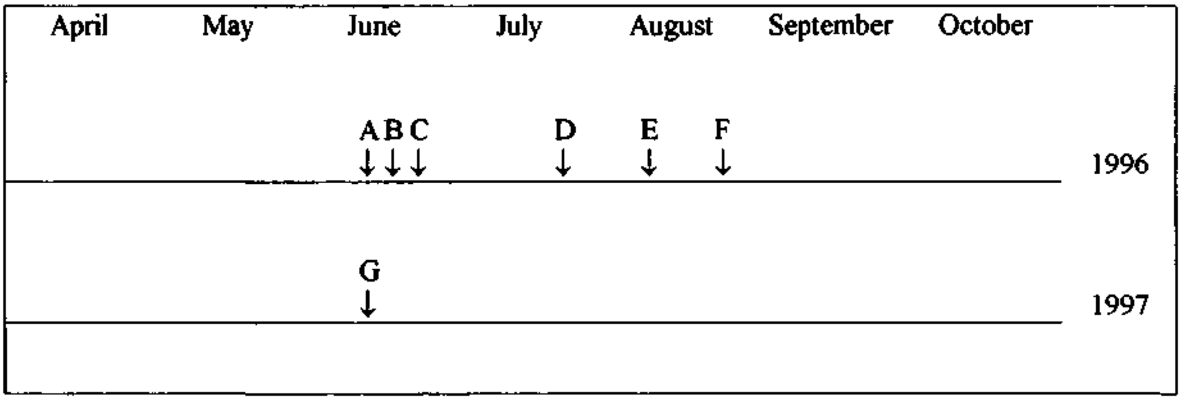


Figure 3. A schematic of the aeration system in Lake Evergreen



Notes:

A - Aerator was installed and started, June 16, 1996
B - Unit shut down due to power connection inadequacies, June 21
C - Restarted, June 28
D - Unit shut down due to power supply problem, July 22
E - Restarted, August 9
F - Pump motor problem shut down unit for rest of the year, August 29
G - Unit remained operational for the rest of the monitoring period after motor was repaired and reinstalled, June 18, 1997

Figure 4. Time line of destratifier operation

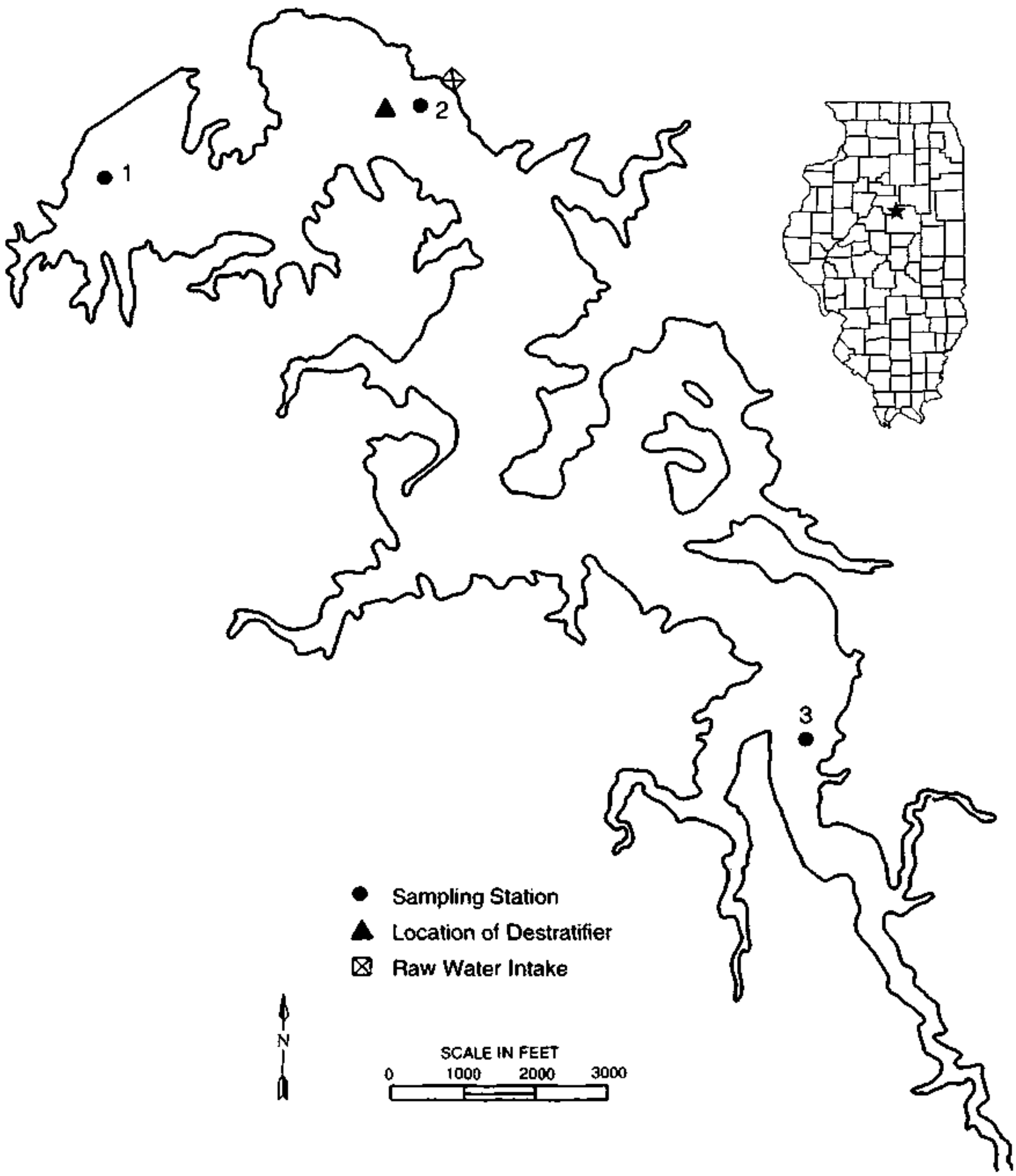


Figure 5. Location of the aeration device and sampling stations in Lake Evergreen

Table 2. Analytical Procedures Used for Chemical Analyses

Turbidity	Nephelometric method, using Turner Fluorometer (model 110), Formazine used as a standard
pH	Glass electrode method with portable Metrohm-Herisau meter (model E588)
Total alkalinity	Titration with standard sulfuric acid solution to an end point pH of 4.5 using glass electrode
Conductivity	Yellow Springs Instrument model 33 conductivity meter corrected to 25°C
Total Phosphorus	Sample was digested with sulfuric nitric acid mixture and determined by ascorbic acid method
Dissolved Phosphorus	Sample was field filtered (0.45 urn), digested with sulfuric, nitric acid mixture and determined by ascorbic acid method
Ammonia-N	Phenate method
Nitrate & Nitrite-N	Automated cadmium reduction method
Suspended solids	Dry weight of solids retained on Gooch crucible with fiberglass filter (Whatman 934-AH)
Total dissolved solids	Residue on evaporation overnight of filtrate on a steam bath at 103- 105°C
Volatile solids	Loss of weight of suspended solids at 550°C ignition for 15 to 20 minutes

margin. When the thermal stratification is established, the lake enters the summer stagnation period, so named because the hypolimnion becomes stagnated.

With cooler air temperatures during the fall season, the temperature of the epilimnion decreases until it is the same temperature as the upper margin of the thermocline. Successive cooling through the thermocline to the hypolimnion results in a uniform temperature through the water column. The lake then enters the fall circulation period (fall turnover) and is again subjected to a complete mixing by the wind.

Declining air temperatures and the formation of an ice cover during the winter produce a slight inverse thermal stratification. The water column is essentially uniform in temperature at about 3 to 4°C, but slightly colder temperatures of 0 to 2°C prevail just below the ice. With the advent of spring and gradually rising air temperatures, the ice begins to disappear, and the temperature of the surface water rises. The lake temperature again becomes uniform, and spring circulation occurs.

The most important phase of the thermal regime from the standpoint of eutrophication is the summer stagnation period. The hypolimnion, by virtue of its stagnation, traps decaying plant and animal matter, thus decreasing the availability of nutrients during the critical growing season. In a eutrophic lake, the hypolimnion becomes anaerobic or devoid of oxygen because of the increased content of highly oxidizable material and because of its isolation from the atmosphere. The absence of oxygen leads to conditions favorable for chemical reduction, and more nutrients are released from the bottom sediments to the overlying waters.

However, during the fall circulation period, the lake water becomes mixed, and the nutrient-rich hypolimnetic waters are redistributed. Nutrients that remained trapped during the stagnation period become available during the following growing season. Therefore, a continual supply of plant nutrients from the drainage basin is not mandatory for sustained plant production. After an initial stimulus, the recycling of nutrients within a lake might be sufficient to sustain highly productive conditions for several years.

Also, it is common knowledge that the impoundment of water alters its physical, chemical, and biological characteristics. The literature is replete with detailed reports on the effects of impoundments on various water quality parameters. Physical changes in the configuration of the water mass after impoundment reduce reaeration rates to a small fraction of those of free-flowing streams. Where the depth of impoundment is considerable, the thermal stratification acts as an effective barrier to the wind-induced mixing of the hypolimnetic zone. Oxygen transfer to the deep waters is essentially confined to the molecular diffusion transport mechanism.

During the period of summer stagnation and increasing water temperatures, the bacterial decomposition of the bottom organic sediments exerts a high rate of oxygen demand on the overlying waters. When this rate of oxygen demand exceeds the oxygen replenishment by molecular diffusion, anaerobic conditions begin to prevail in the zones adjacent to the lake bottom. Hypolimnetic zones of man-made impoundments in Illinois were also found to be anaerobic within a year of their formation.

The data collected for station 2 are more complete than those for station 1 and are much more significant because of the closeness to the aerator and the water intake. Consequently, station 2 is dealt with before station 1 in presenting the results and discussions in the report.

Figure 6 shows isothermal and isodissolved oxygen plots for the years 1996 and 1997 for Lake Evergreen at station 2, near the raw water intake. Figure 7 shows similar plots for station 1, which is approximately 5,000 feet away from the aerator location. Appendix A includes the observed temperature and DO data for all three monitoring stations.

Raman and Twait (1994) reported that thermal stratification began in mid-May in Lake Evergreen and anoxic conditions prevailed in the hypolimnetic zone at depths below 20 feet from the surface at station 2. The maximum depth of water at station 2 at the time of investigation was 29 feet before the lake level was raised in 1996. The lower of the two water intakes (690 ft-msl) was totally in the anoxic hypolimnetic zone. The lake became isothermal with improved oxygen conditions in the deeper waters towards the middle of September.

Figure 6 indicated that even though the aerator was installed in mid-June of 1996 and operated intermittently (figure 4), there was no pronounced thermal stratification at the station. Anoxic conditions that began to develop in the lake prior to the installation of the aerator (June 16, 1996) were alleviated within a short period thereafter, and the anoxic zone extended to a depth of 10 feet above the bottom. There were two isolated episodes of anoxic conditions at station 2 concurrent with the shutdowns of the aerator.

Again in 1997, when the aerator operated continuously from June 18 without interruptions, the lake remained nearly isothermal, with a maximum temperature gradient of 2.9°C, whereas the maximum temperature gradient observed in the earlier study at station 2 was 11.5°C when the lake was 5 feet shallower. There was one episode of anoxic conditions at station 2 in July 1997 extending to a depth of 12 feet from the bottom. This was, however, very short lived. This was probably due to the algal die-off subsequent to the algal bloom noted on June 5, 1997, when super saturated conditions of 20^+ mg/L of DO concentrations prevailed throughout the water column in the lake (tables A-4, A-5, and A-6 in appendix A). DO conditions in the lake at station 2, near the raw water intake, were found to be significantly improved in spite of the increased water depth compared to the pre-aeration period.

Figure 7 shows the isothermal and isodissolved oxygen plots at station 1, about 5,000 feet away from the aerator and near the dam. It is seen that the lake is destratified to a depth of 30 feet, the depth at which the aeration system is sited (near station 2), and that the anoxic conditions are alleviated up to a depth of 30 feet from the surface, even at station 1. The aeration system appears to be effective in improving DO conditions

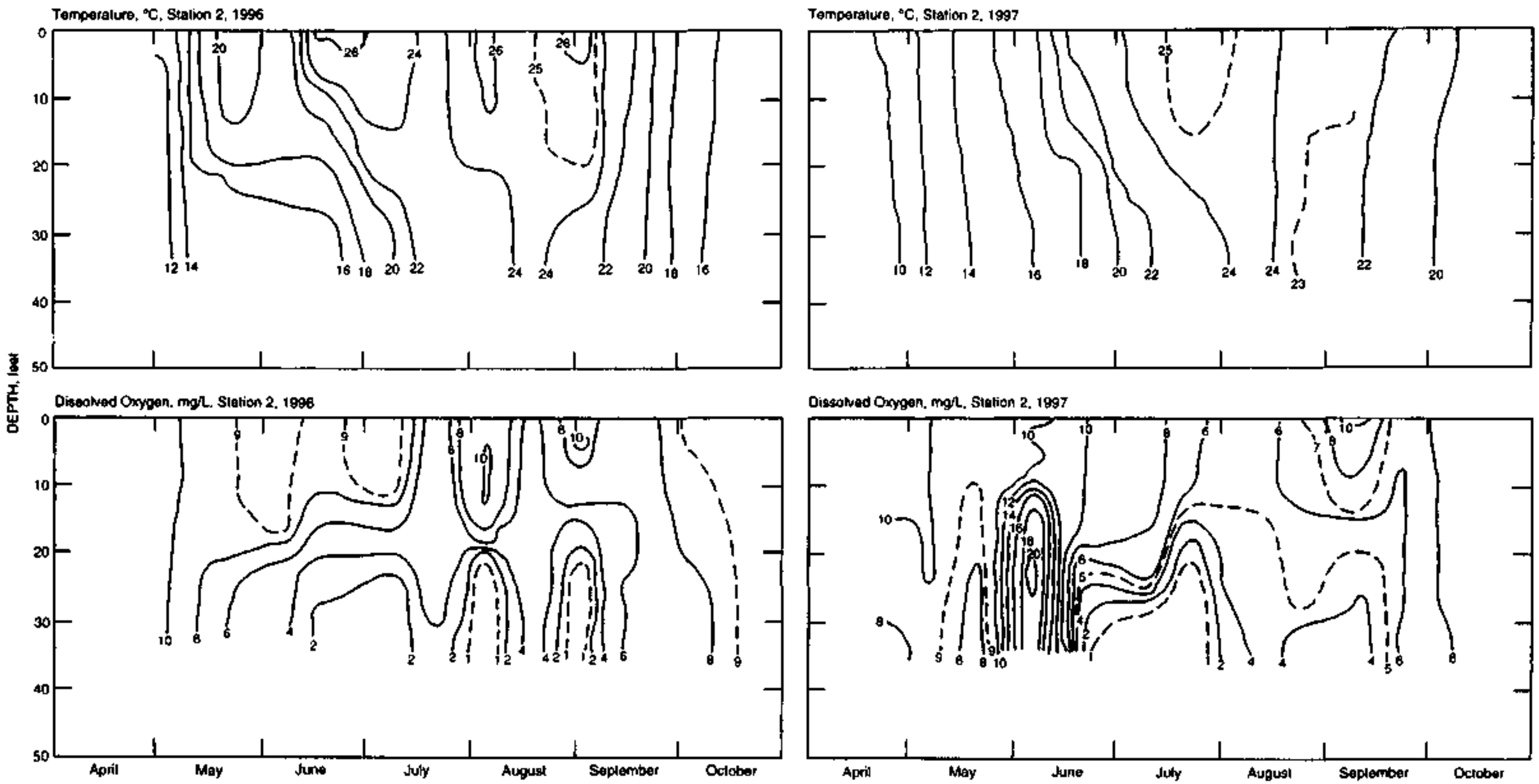


Figure 6. Isothermal and isodissolved oxygen plots at station 2, 1996 and 1997

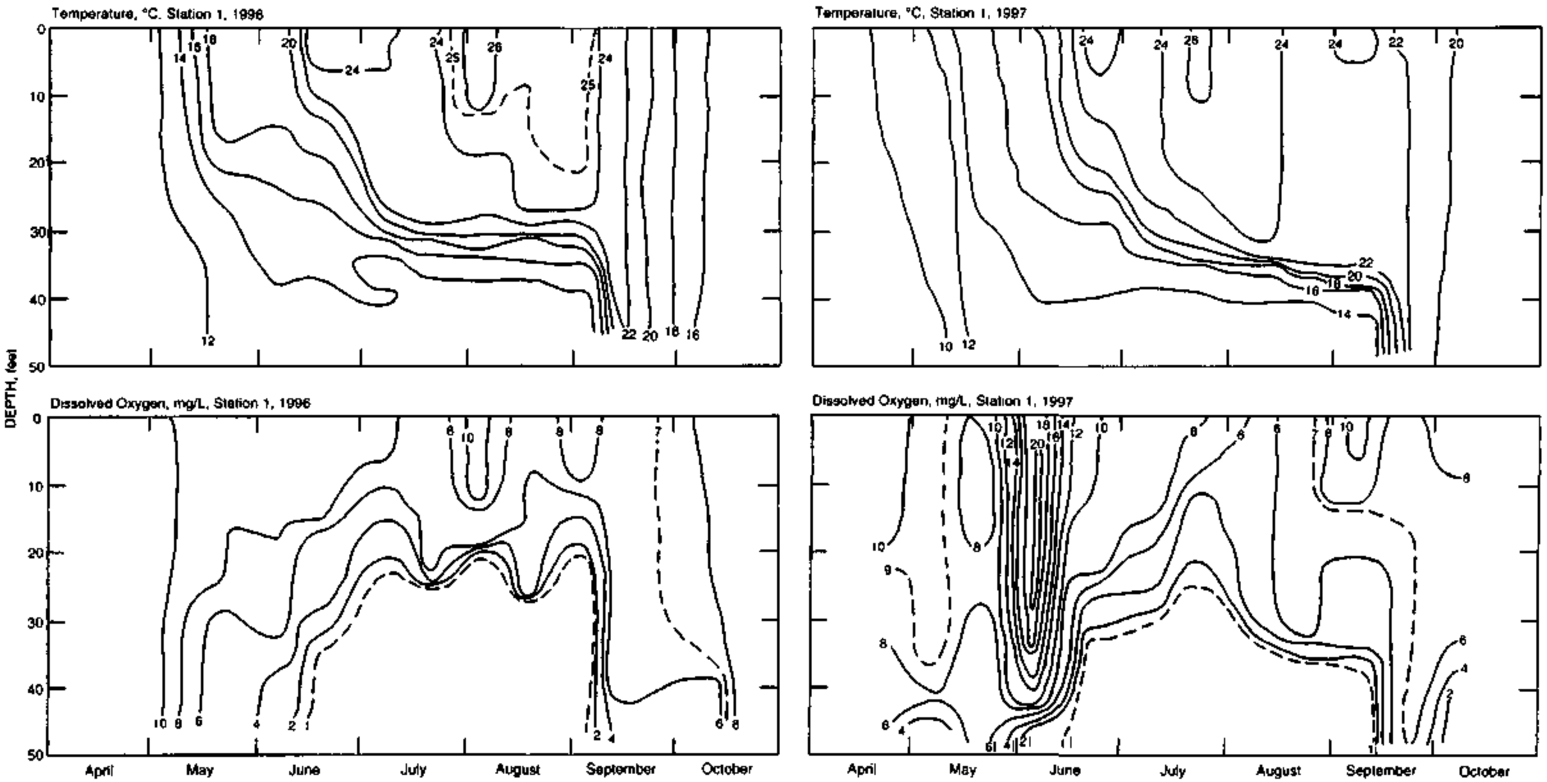


Figure 7. Isothermal and isodissolved oxygen plots at station 1, 1996 and 1997

throughout the lake, up to the depth of its operation, irrespective of the location of the aerator.

DO conditions could have been enhanced much more, if the aerator were located at the deepest point in the lake near the dam. However, bringing power to the site, the need for a heavier duty power cable required by a longer power cable, and higher horsepower system because of increased water depth, etc. would all have made the total cost of the project prohibitive. With the current installation, only 5.4 percent of the lake volume is likely to remain anoxic during summer thermal stratification and the raw water intake ports will be higher than the anoxic zone.

Figures 8-10 show vertical temperature and DO profiles on selected dates in 1997 for stations 2, 1, and 3 respectively. For purposes of comparison, figures 11 and 12 show profiles for station 2 during the earlier study (Raman and Twait, 1994).

The profiles on June 23, 1997 at station 2 (figure 8) show DO and temperature gradients resulting from the fact that the aerator was repaired and reinstalled only a few days prior to the lake monitoring. It normally takes a few days to destratify the lake once stratification occurs in summer. Profiles for June 22, 1997 at station 2 indicate that the lake is nearly isothermal, but there was significant DO depletion for reasons discussed earlier. Otherwise, the DO and temperature were uniform throughout the water column. This was true at the shallow station, station 3. Profiles shown in figure 9 for station 1 clearly show the effectiveness of the aeration system up to a depth of about 30 feet.

Figure 11 shows the significant temperature gradients at station 2 at depths below 20 feet during summer stratification before destratification. Figure 12 brings out dramatically the lack of oxygen in the lake at depths below 20 feet from the water surface during summer stratification. The beneficial impact of the aeration system in enhancing the DO conditions in the deeper waters during summer stratification is readily apparent.

Figure 13 is a schematic of the raw water intake structure in Lake Evergreen. The two intake ports located at 705 and 690 ft-msl will be taking in fairly well oxygenated lake water. Raw water withdrawal from the anoxic zone had been traced to undesirable taste and odor problems in the finished waters of the potable water supply system.

Appendix B (tables B-1 to B-6) provides percent saturation values calculated based on DO and temperature observations made at all the three monitoring stations during 1996 and 1997. Tables B-4 and B-5 reinforce the observations made about DO at stations 1 and 2; namely, supersaturated conditions existed in the lake on June 5, 1997, prior to the re-installation and start-up of the aerator. Oxygen depletion near the lake bottom on July 22 was probably due to algal die-off. Except for this single episode, DO conditions in the water column at station 2 during 1997 were good to excellent. The aeration system is effective in improving DO conditions in the lake up to depths of 30 feet, even at station 1 about 5000 feet away and downstream of the aerator.

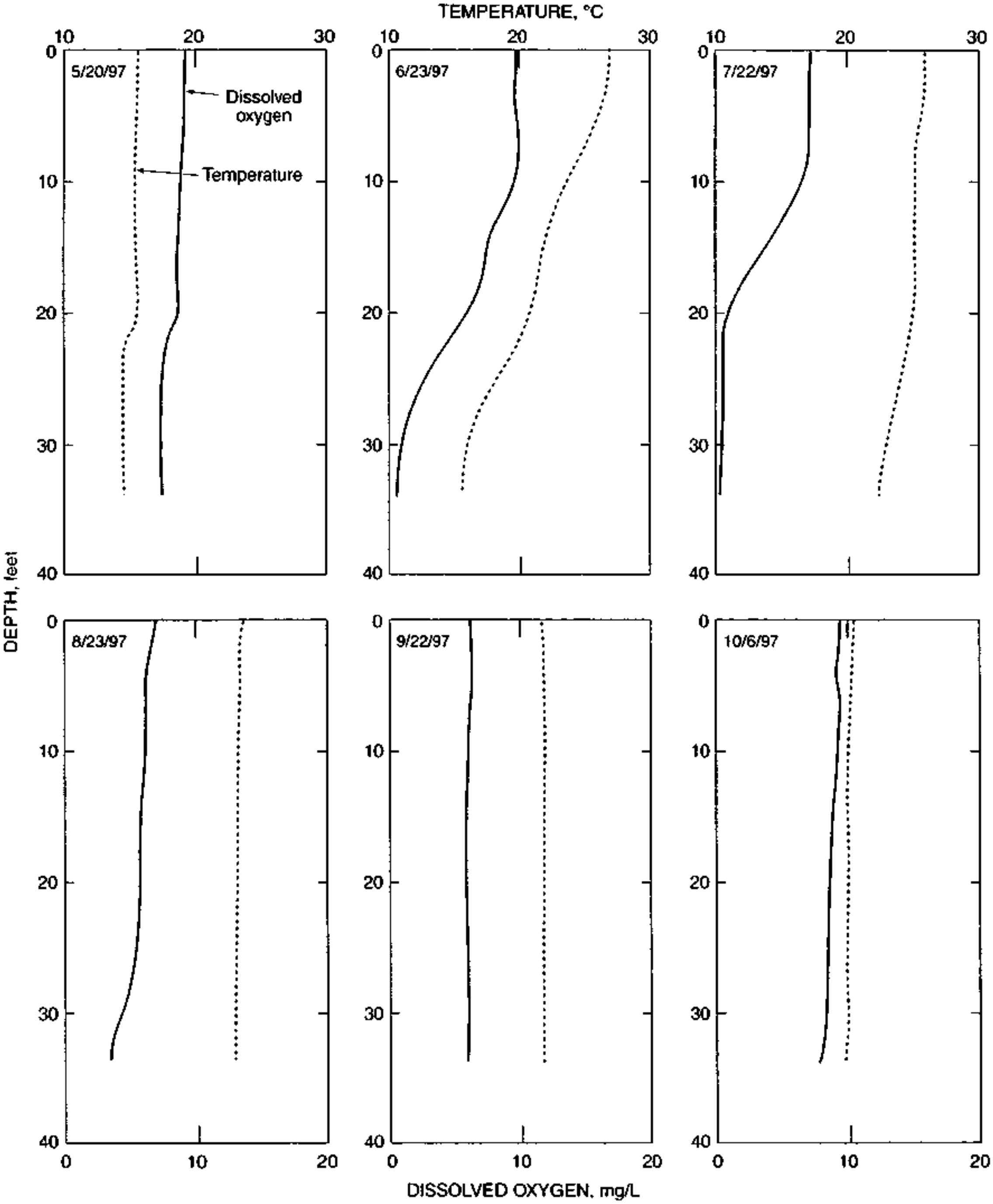


Figure 8. Temperature and dissolved oxygen profiles at station 2 on selected dates, 1997

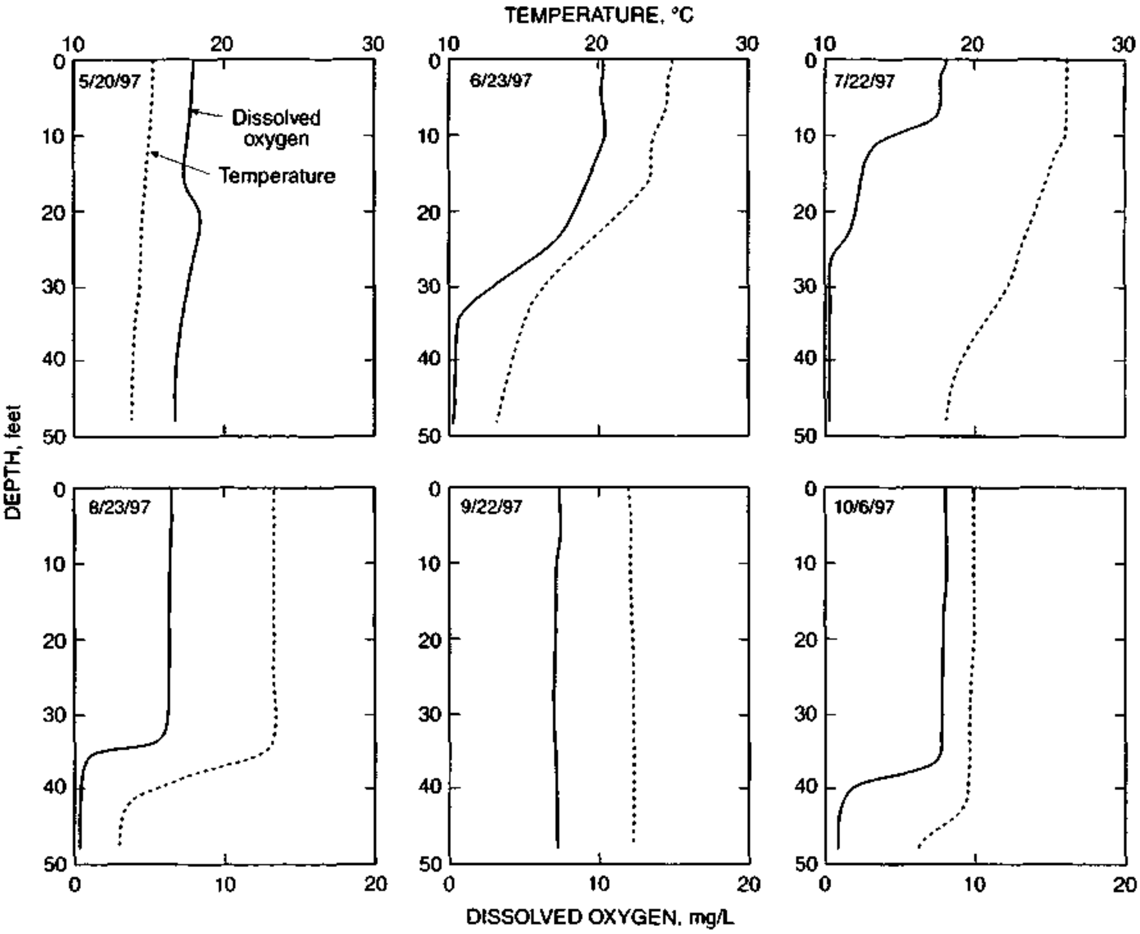


Figure 9. Temperature and dissolved oxygen profiles at station 1 on selected dates, 1997

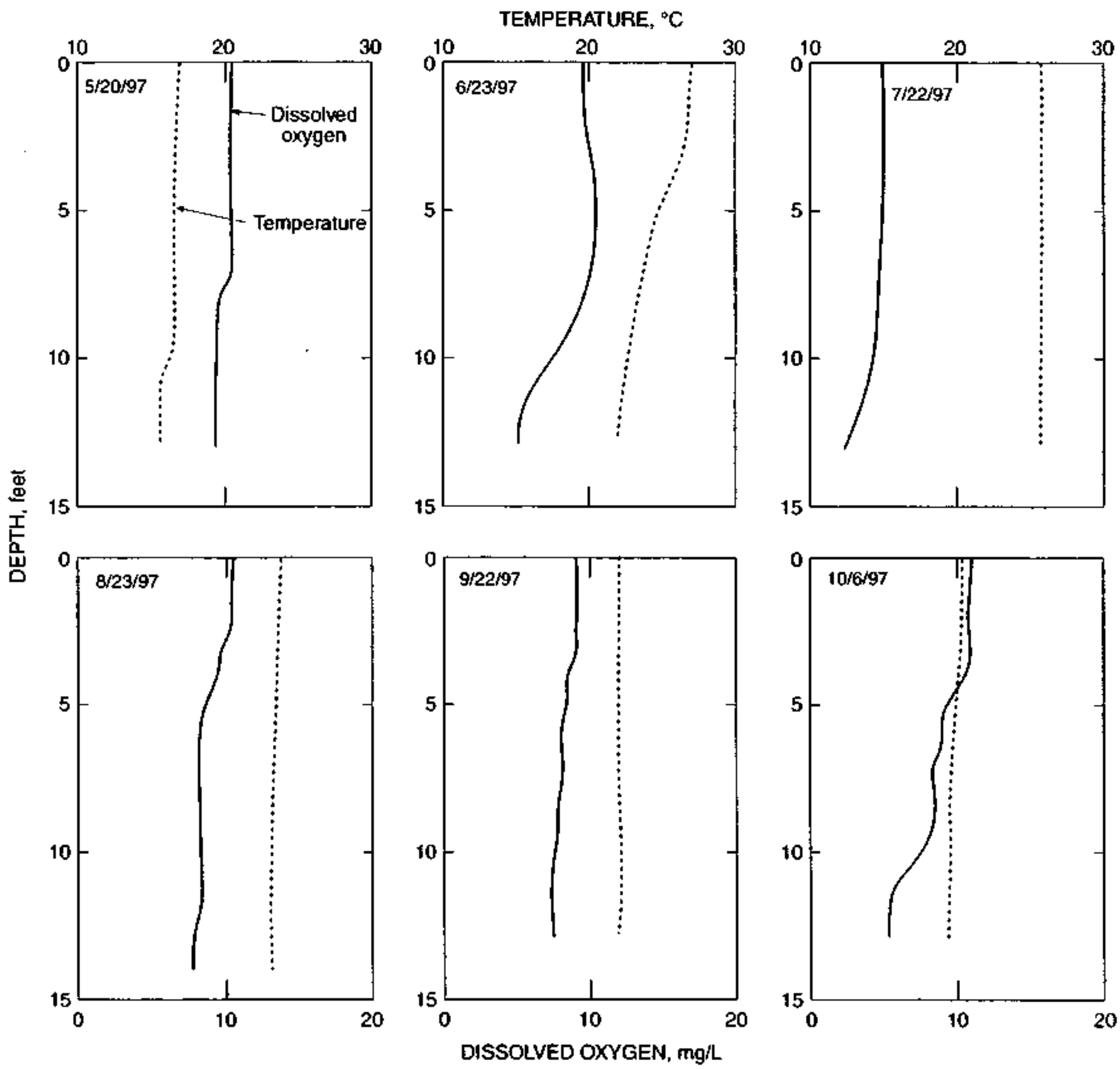


Figure 10. Temperature and dissolved oxygen profiles at station 3 on selected dates, 1997

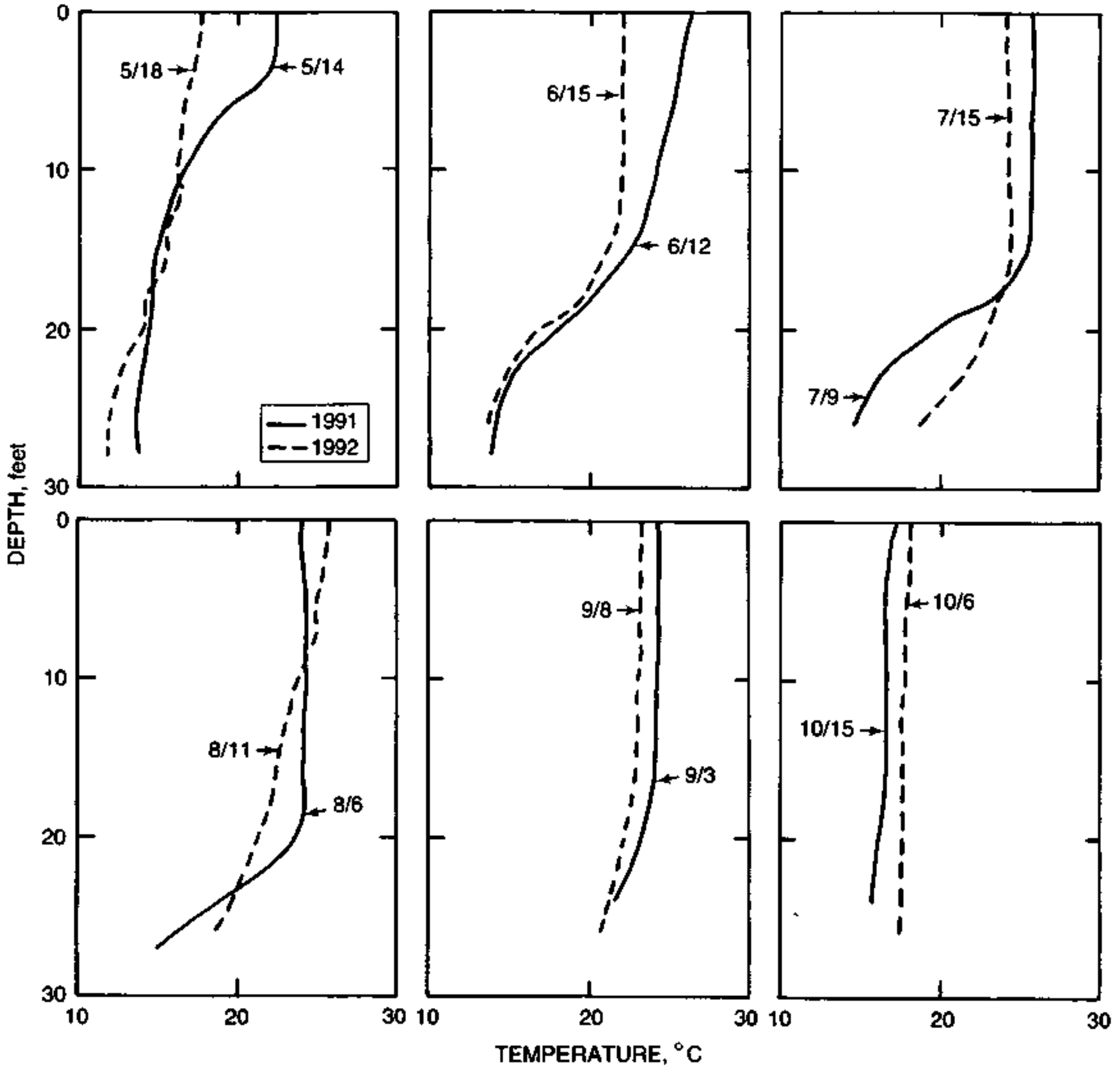


Figure 11. Temperature profiles at station 2 of Lake Evergreen
on selected dates (Raman and Twait, 1994)

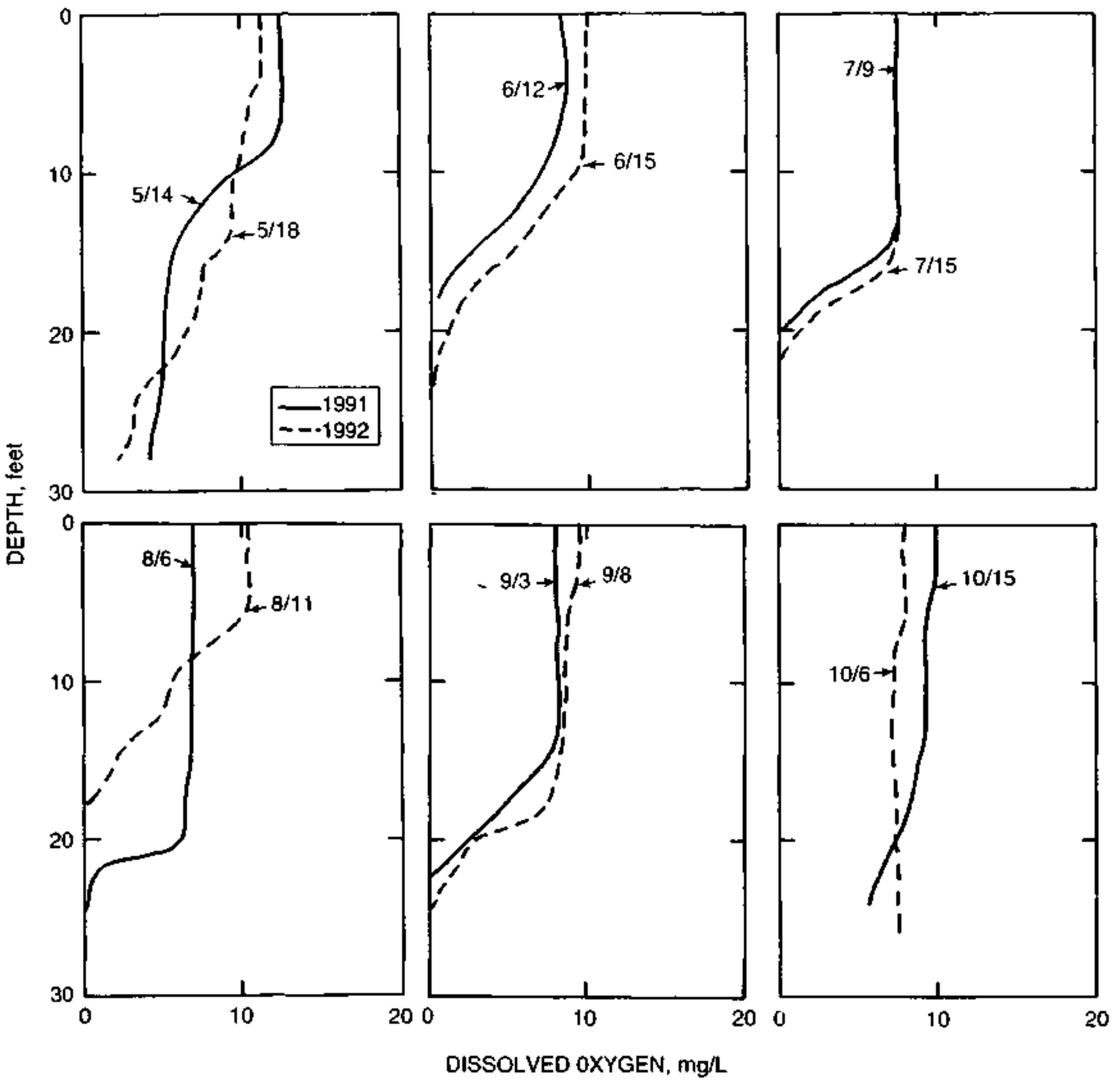


Figure 12. Dissolved oxygen profiles at station 2 of Lake Evergreen on selected dates (Raman and Twait, 1994)

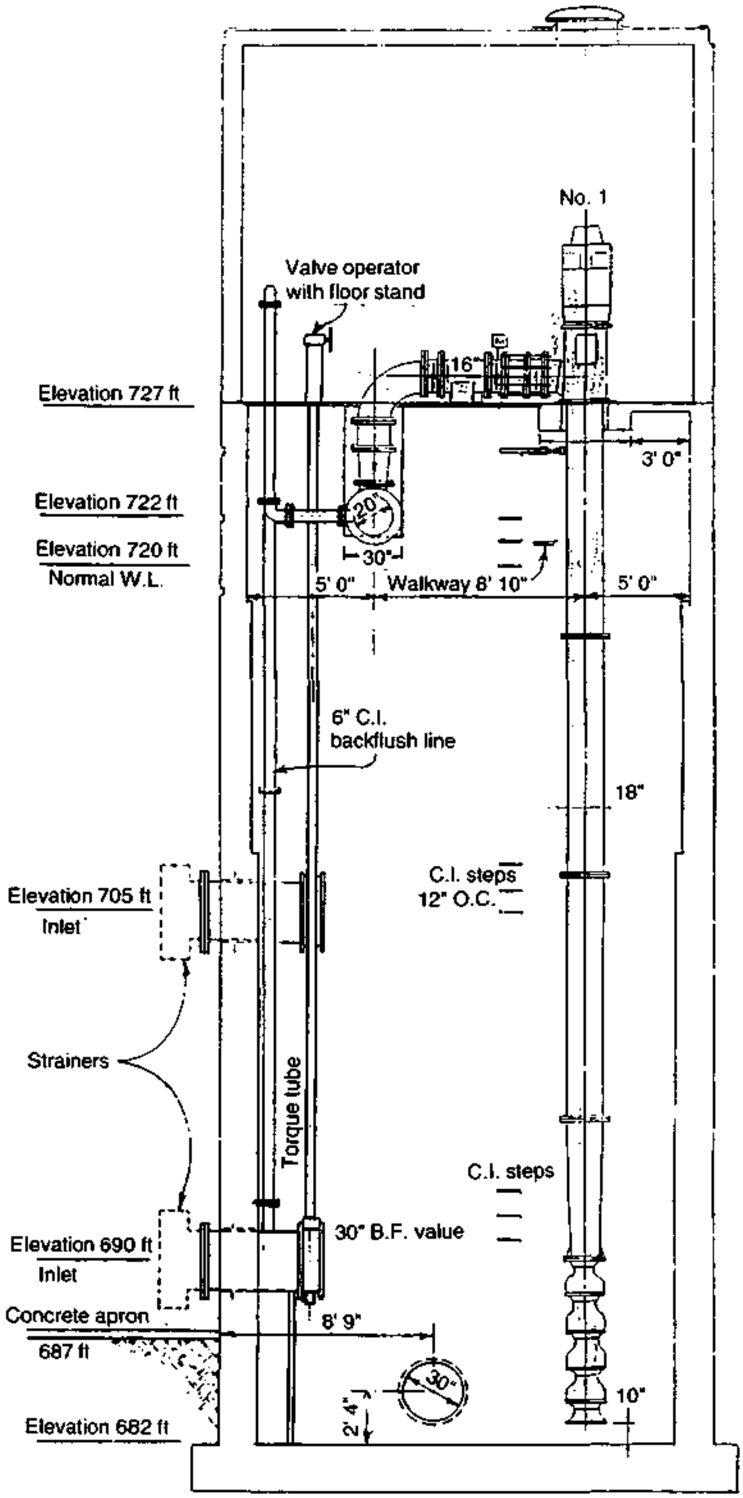


Figure 13. Wet well intake in Lake Evergreen

Appendix C (tables C-1 to C-8) includes other physical and chemical water quality data gathered for the lake during 1996 and 1997 for stations 1, 2, and 3. The near bottom water quality characteristics were monitored only for station 2 near the raw water intake.

Turbidity and Secchi Disc. Summaries of other physical water quality characteristics along with chemical quality characteristics are presented in tables 3-5, respectively, for stations 2, 1, and 3. For purposes of comparison, table 6 provides summaries of water quality characteristics at station 2 for the years 1991 and 1992 as reported by Raman and Twait (1994).

Comparing tables 2 and 5, it is seen that the turbidity and secchi disc values for the lake at station 2 have improved significantly. The same is true for station 3. Station 1 was not monitored in the earlier study. The decrease in turbidity and increase in secchi disc values are in major part due to the increased lake level. Installation and start-up of the aerator has not increased turbidity or decreased transparency.

Chemical Characteristics

The range of pH values observed before and after the installation of the aerator are comparable. The surface mean of total alkalinity increased in 1996 and 1997 compared to the values for 1991 and 1992, probably due to decreased algal activity. However, the mean and range of values for conductivity remained comparable, as were the observations for total dissolved and suspended solids. These observations hold true for the near bottom waters also.

There are perceptible differences in the means of total phosphate values for surface samples between the two sets of periods under consideration. Total phosphate was 50 percent higher in 1996 and 25 percent lower in 1997 than during the pre-aeration period. However, all these values; namely, 0.06, 0.03, 0.04, and 0.04 mg/L for the years 1996, 1997, 1991, and 1992, are much lower than the values observed for some other Illinois lakes.

Ammonia values found in the lakes are well within the Illinois Pollution Control Board's standards. Surface values were almost identical for the pre- and post-aeration periods. However, the near bottom water sample values are significantly lower for the post-aeration period, 0.10 milligrams per liter or mg/L in 1996 and 0.16 mg/L in 1997, compared to the pre-aeration period values, 0.21 mg/L in 1991 and 0.24 mg/L in 1992 (tables 3 and 6). This reduction in ammonia concentrations in the near bottom waters is attributable to the improved oxygen conditions in the deeper zones due to aeration.

A noteworthy aspect of this investigation is that the nitrate levels in the lake never exceeded the drinking water standard of 10 mg/L as nitrogen. The mean of surface nitrate plus nitrite-N levels were 3.53 and 2.14 mg/L in 1996 and 1997, respectively, and 9.52 and 5.51 in 1991 and 1992. Values for near bottom waters were 3.65 and 2.02 in 1996 and 1997 and 8.67 and 5.19 in 1991 and 1992, respectively. For the pre-aerator period (1991), there were several instances of nitrate values higher than the standard of 10 mg/L

Table 3. Water Quality Characteristics of Lake Evergreen, Station 2

	Surface				*Near Bottom*			
	1996		*1997*		*1996*		*1997*	
Parameters	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*
Secchi readings (inches)	43	22-91	54	31-105	-	-	-	
Turbidity, NTU	8	4-15	5	1-9	19	6-39	16	2-40
pH (units)	-	8.16-8.64	-	8.18-8.71	-	7.76-8.64	-	7.85-8.43
Total alkalinity	174	162-193	165	153-179	178	162-193	170	140-193
Conductivity, umho/cm	507	474-549	506	470-542	516	474-559	521	436-561
Total suspended solids	7	1-19	6	2-12	18	8-33	11	4-94
Volatile suspended solids	3	1-6	3	0-6	5	0-0	4	0-14
Dissolved solids	303	264-336	297	264-352	309	260-336	304	271-356
Total phosphate-P	0.06	0.02-0.29	0.03	0.01-0.04	0.07	0.03-0.12	0.05	0.02-0.12
Dissolved phosphate-P	0.01	<0.01-0.03	0.01	<0.01-0.02	0.02	<0.01-0.06	0.01	<0.01-0.03
Nitrate & Nitrite-N	3.53	1.46-5.74	2.14	0.51-3.62	3.65	1.18-6.81	2.02	0.51-3.42
Ammonia-N	0.07	0.02-0.15	0.06	<0.02-0.15	0.10	0.02-0.17	0.16	0.02-0.28

Note: Values in mg/L unless otherwise indicated.

Table 4. Water Quality Characteristics of Lake Evergreen, Station 1, Surface

Parameters	*1996* *Mean*	*1996* *Range*	*1997* *Mean*	*1997* *Range*
Secchi readings (inches)	55	30-103	67	31-109
Turbidity, NTU	5	2-11	4	1-9
pH (units)	-	8.24-8.64	-	8.22-8.62
Total alkalinity	173	160-192	163	147-175
Conductivity, µmho/cm	505	478-556	505	466-534
Total suspended solids	4	1-7	5	2-9
Volatile suspended solids	2	0-5	.2	1-5
Dissolved solids	296	268-326	295	254-330
Total phosphate-P	0.03	0.02-0.04	0.02	0.01-0.05
Dissolved phosphate-P	0.01	<0.01-0.02	0.01	<0.01-0.02
Nitrate & Nitrite-N	3.44	1.39-5.20	2.18	0.51-3.36
Ammonia-N	0.07	0.02-0.08	0.07	<0.02-0.12

Note: Values in mg/L unless otherwise indicated.

Table 5. Water Quality Characteristics of Lake Evergreen, Station 3, Surface

	1996		*7997*	
Parameters	*Mean*	*Range*	*Mean*	*Range*
Secchi readings (inches)	24	13-62	36	26-55
Turbidity, NTU	15	4-28	7	2-11
pH (units)	-	8.05-8.82	-	8.13-8.92
Total alkalinity	183	168-217	168	152-189
Conductivity, µmho/cm	526	476-647	514	465-564
Total suspended solids	16	3-34	9	3-20
Volatile suspended solids	4	1-8	4	0-7
Dissolved solids	317	260-390	306	264-366
Total phosphate-P	0.07	0.05-0.09	0.05	0.02-0.07
Dissolved phosphate-P	0.02	0.01-0.04	0.01	0.01-0.05
Nitrate & Nitrite-N	3.95	1.06-7.83	2.11	0.26-5.26
Ammonia-N	0.11	0.02-0.30	0.04	<0.02-0.19

Note: Values in mg/L unless otherwise indicated.

Table 6. Water Quality Characteristics of Lake Evergreen at Station 2

	1991				*1992*			
	Near surface		*Near bottom*		*Near surface*		*Near bottom*	
Parameter	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*
Secchi readings (inches)	41	17-61	-	-	43	27-52	-	-
Turbidity, NTU	13	9-33	27	11-64	12	10-17	25	15-45
pH (units)	-	8.26-8.80	-	7.68-8.71	-	7.99-8.79	-	7.52-8.52
Total alkalinity	154	142-176	175	145-211	151	132-175	162	141-179
Conductivity (µmho/cm)	520	484-571	544	485-584	498	453-566	513	468-563
Hardness	245	178-271	257	178-289	240	215-284	249	225-277
Total phosphate-P	0.04	0.02-0.09	0.14	0.03-1.09	0.04	0.02-0.06	0.06	0.04-0.08
Dissolved ammonia-N	0.06	0.02-0.13	0.21	0.04-0.56	0.07	0.02-0.15	0.24	0.06-0.46
Nitrate-N	9.35	5.45-12.10	8.50	5.24-12.40	5.44	3.02-7.38	5.08	3.09-7.20
Nitrite-N	0.17	0.03-0.32	0.17	0.03-0.32	0.10	0.05-0.16	0.11	0.05-0.22
Total suspended solids	6	0-19	16	2-53	8	4-13	18	9-40
Total dissolved solids	330	296-398	342	310-384	331	288-382	336	286-374

Note: Values in mg/L unless otherwise indicated
Source: Raman and Twait (1994)

as evidenced by figure 12 of Raman and Twait (1994). The reduction of nitrate levels in the lake is probably due to a combination of factors such as reduced nitrate loadings from the tributary, increased lake volume from raising the spillway level in 1996 causing a dilution effect, reduction in the release of ammonia-N from lake bottom sediments during summer months because of improved hypolimnetic oxygen conditions, increased biological productivity rates due to increase in temperature of the deeper waters resulting from the complete mixing of the lake, etc.

Water quality characteristics observed for the lake were all within the desirable range at all sampling stations. With the improved oxygen conditions in the lake near the water intake and with the desirable changes in the nitrate and ammonia values in the lake as a result of the aeration-destratification, the lake now is a more desirable source of water for the City of Bloomington.

Summary

Subsequent to the experimental destratification effort in Lake Bloomington to improve oxygen conditions with a Dobbs low-volume, high-head floating pump, which proved to be inconsequential, the City of Bloomington chose the Aspir-Air Inc. aeration system for both Lake Evergreen and Lake Bloomington. The device, an aspirated air aeration system, operates on the Venturi principle. When the Illinois State Water Survey tried a similar system in Lake Catherine in Lake County, Illinois, it was found to significantly improve the lake's physical, chemical, and biological water quality characteristics. The 40-horsepower aeration system was installed in Lake Evergreen on June 16, 1996, near the water intake structure at a water depth of about 34 feet.

Because of some power supply and equipment problems, the system operated only intermittently during 1996. After rectifying all the problems, the system was restarted on June 18, 1997, and operated continuously for the remainder of the summer and fall seasons. This investigation summarizes the effects of destratification in Lake Evergreen during 1996 and 1997 using observations made in the lake during 1991 and 1992 as a basis for comparison.

When the aerator operated continuously without interruptions, the lake remained nearly isothermal up to a depth of 30 feet, the depth at which the system was operating. DO conditions in the entire water column near the water intake improved significantly compared to the pre-aeration period. The destratifier was also effective near the dam up to a depth of 30 feet from the surface even though the monitoring site was nearly 5,000 feet downstream of the aerator location. The 40-horsepower system was able to enhance DO conditions in nearly 95 percent of the lake volume.

Turbidity and secchi disc values for the lake improved significantly. The increase in lake transparency and decrease in turbidity are in large part due to the increased lake depths after the spillway level was raised by 5 feet in 1996.

The range of pH values observed before and after the aerator installation was comparable. However, total alkalinity values were higher in the post-destratification period, indicating reduced algal activities.

There were perceptible differences in the total phosphate-P values observed before and after destratification, but no definitive trend could be discerned. However, the phosphate levels in the lake were much lower compared to the values observed in other Illinois lakes.

Ammonia-N values were well within the Illinois general use standards. Surface values were almost identical for the pre- and post-aeration periods. However, the near bottom water samples values were significantly lower for the post-aeration period. This reduction of ammonia in the near bottom waters is attributable to the improved oxygen conditions in the deeper waters due to aeration. A noteworthy aspect of this investigation is that the nitrate levels in the lake never exceeded the drinking water standard of 10 mg/L as nitrogen. Nitrate levels were found to be significantly higher in the earlier investigation and were found to exceed the standard several times.

With the improved oxygen conditions in the lake near the water intake and with the desirable changes in the ammonia and nitrate levels as a result of lake aeration/destratification, the lake serves as a more desirable raw water source to the City of Bloomington.

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Appendix A.
Dissolved Oxygen and Temperature Observations

Table A-1. Dissolved Oxygen and Temperature Observations at Station 1, 1996

	5/2		5/20		6/7		6/19		6/20		7/9		7/22		8/5		8/19		9/3		9/16		10/7	
Depth	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
0	11.9	10.2	19.0	9.1	19.4	9.8	24.2	9.1	26.2	8.9	24.1	8.4	23.9	6.7	26.4	10.4	25.1	6.0	26.6	9.0	22.2	6.2	16.9	8.0
2	11.9	10.3	19.0	9.1	19.4	9.8	24.2	9.1	25.6	9.3	24.0	8.5	23.9	6.7	26.4	10.4	25.1	6.1	26.6	9.1	22.3	6.2	16.9	8.0
4	11.7	10.3	19.0	9.1	19.4	9.8	24.1	9.1	24.5	9.8	24.0	8.5	23.9	6.7	26.3	10.4	25.1	6.1	26.4	9.2	22.3	6.2	16.9	7.9
6	11.7	10.4	19.0	9.1	19.3	9.8	23.9	9.1	24.4	9.8	24.0	8.5	23.9	6.8	26.3	10.5	25.1	6.1	26.4	9.8	22.3	6.3	16.9	7.9
8	11.7	10.4	18.9	9.1	19.1	9.7	23.7	9.2	24.0	9.9	23.9	6.2	23.9	6.8	26.3	10.5	25.0	6.0	26.4	10.4	22.3	6.3	16.9	7.9
10	11.7	10.4	18.9	9.1	18.5	9.1	22.2	9.6	22.9	9.6	23.7	5.5	23.9	6.7	26.2	10.4	25.0	6.0	25.8	7.2	22.3	6.3	16.9	7.8
12	11.6	10.4	18.9	9.1	18.3	8.9	21.0	9.2	21.3	8.9	23.5	4.9	23.9	6.7	26.1	10.2	25.0	6.0	25.7	5.4	22.3	6.4	16.9	7.8
14	11.6	10.4	18.6	9.0	18.1	8.8	19.3	9.4	20.2	8.3	23.4	4.4	23.9	6.7	24.8	7.9	25.0	6.0	25.4	4.6	22.3	6.4	16.9	7.7
16	11.6	10.4	18.1	8.9	17.9	8.7	18.6	6.2	19.1	7.8	22.2	3.8	23.9	6.7	24.6	7.1	25.0	6.0	25.3	3.0	22.3	6.4	16.9	7.5
18	11.6	10.4	17.7	8.8	17.2	8.0	18.2	5.6	18.6	6.9	22.9	3.3	23.9	6.7	24.5	6.5	24.9	5.8	25.2	2.1	22.3	6.4	16.9	7.4
20	11.6	10.5	16.4	8.5	16.7	7.5	17.6	5.2	17.9	6.6	22.7	2.3	23.9	6.7	23.9	1.4	24.9	5.7	25.1	1.5	22.3	6.5	16.9	7.3
22	11.6	10.5	14.8	8.4	16.3	7.3	17.0	5.1	17.2	6.0	22.2	1.3	23.9	6.3	23.5	0.2	24.9	5.7	25.0	0.6	22.3	6.5	16.8	7.3
24	11.6	10.5	14.1	8.2	16.0	7.1	16.6	5.0	16.5	5.4	22.1	0.9	23.9	4.2	23.1	0.1	24.9	5.8	24.8	0.4	22.3	6.5	16.8	7.2
26	11.5	10.4	13.5	7.4	15.6	6.7	16.0	4.7	15.9	4.9	22.1	0.3	23.6	0.9	22.7	0.1	24.9	5.7	24.4	0.4	22.3	6.5	16.8	7.1
28	11.5	10.4	13.2	6.9	15.4	6.6	15.6	4.3	15.5	4.8	20.7	0.2	22.9	0.1	22.0	0.1	23.2	0.3	23.4	0.4	22.3	6.5	16.8	7.1
30			12.9	5.6	15.4	6.6	15.2	3.5	15.0	4.0	18.8	0.2	21.5	0.1	20.6	0.1	20.5	0.2	21.4	0.4	22.3	6.4	16.8	7.1
32			12.9	5.6	15.2	6.2	14.7	2.6	14.7	3.5	15.8	0.2	17.7	0.1	18.3	0.1	17.6	0.2	18.4	0.4	22.3	6.3	16.8	7.1
34			12.3	4.0	14.7	5.7	14.3	1.1	14.5	2.9	13.9	0.2	15.3	0.1	16.0	0.2	16.1	0.2	16.3	0.4	22.3	6.3	16.8	7.0
36					14.4	5.4	14.1	0.5	14.2	2.1	13.9	0.2	14.1	0.1	14.4	0.2	14.6	0.2	15.0	0.4	22.3	6.3	16.8	7.0
38					14.0	3.6	13.9	0.2	14.1	0.6	13.9	0.2	13.6	0.1	13.8	0.2	13.8	0.2	14.3	0.4	22.2	6.3	16.8	6.8
40					13.5	2.5	13.7	0.2	13.8	0.5	13.7	0.2	13.3	0.1	13.4	0.2	13.2	0.2	13.5	0.4	21.8	6.2	16.5	3.9
42											13.4	0.2	13.1	0.1	13.2	0.2	13.1	0.2	13.1	0.4	22.2	6.3	16.3	0.2
44													12.9	0.1	12.1	0.2					22.0	5.9	16.0	0.2

Note: Units of measurements are: depth - feet, temperature - °C, and DO - mg/L.

Table A-2. Dissolved Oxygen and Temperature Observations at Station 2, 1996

	5/2		5/20		6/7		6/19		6/20		7/9		7/22		8/5		8/19		9/3		9/16		10/7	
Depth	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
0	12.1	10.7	20.6	8.8	19.7	9.3	24.6	8.8	26.7	9.4	2J.0	9.8	23.6	5.7	26.1	9.9	25.0	5.9	26.5	9.8	22.3	6.6	17.3	9.2
2	12.1	10.7	20.6	8.8	19.7	9.3	24.6	8.8	25.3	9.7	25.0	9.9	23.7	5.7	26.1	9.9	25.0	5.9	26.3	9.8	22.3	6.6	17.3	9.2
4	12.0	10.7	20.6	8.8	19.7	9.3	24.4	8.7	24.7	9.8	25.0	9.9	23.6	5.6	26.1	10.0	25.0	5.9	26.1	10.1	22.3	6.6	17.3	9.1
6	11.9	10.3	20.5	8.8	19.6	9.3	24.2	8.8	24.5	9.8	25.0	9.9	23.7	5.6	26.1	10.0	25.0	5.9	25.8	8.6	22.3	6.7	17.3	9.0
8	11.9	10.3	20.5	8.8	19.5	9.2	24.1	8.8	23.9	9.2	25.0	9.9	23.7	5.6	26.0	10.0	24.9	5.8	25.6	7.4	22.2	6.4	17.3	8.8
10	11.8	10.3	20.4	8.8	19.5	9.2	23.7	8.1	21.9	8.0	25.0	9.9	23.7	5.6	26.0	10.0	24.9	5.8	25.5	6.8	22.1	6.2	17.2	8.4
12	11.8	10.3	20.3	8.7	19.5	9.2	20.6	6.6	20.7	7.4	24.8	8.3	23.7	5.6	26.0	10.0	24.9	5.7	25.4	6.1	22.0	6.2	17.1	8.1
14	11.8	10.3	19.8	8.7	19.4	9.1	19.6	7.2	19.9	6.6	24.2	6.8	23.7	5.6	25.9	9.9	24.9	5.7	25.4	4.5	21.9	5.6	17.0	8.2
16	11.8	10.3	19.4	8.6	19.4	9.1	18.8	5.8	19.1	5.9	23.8	6.2	23.7	5.5	25.7	8.9	24.9	5.7	25.3	3.8	21.9	5.6	16.9	8.3
18	11.8	10.2	19.2	8.6	19.3	8.9	18.0	5.0	18.7	5.8	22.9	5.9	23.6	5.4	24.9	6.6	24.8	5.7	25.2	2.6	21.8	5.7	16.9	8.4
20			17.9	8.1	17.5	6.6	17.5	4.4	17.9	5.6	22.8	3.8	23.6	5.4	24.1	1.8	24.8	5.6	25.0	1.4	21.7	5.6	16.9	8.5
22			15.2	6.1	16.6	5.4	17.2	3.5	17.1	3.8	22.4	3.7	23.6	5.4	23.8	0.2	24.8	5.4	24.8	0.3	21.6	5.3	16.8	8.2
24					16.4	5.3	16.8	2.8	16.8	3.3	22.0	1.1	23.6	5.4	23.5	0.2	24.8	5.4	24.4	0.2	21.4	6.1	16.6	7.7
26					16.0	5.3	16.5	2.7	16.4	2.6	21.7	0.8	23.6	5.5	22.8	0.1	24.8	5.4	23.9	0.2	21.2	6.1	16.4	7.7
28					15.4	4.7	16.0	1.5	15.9	2.4	20.0	0.2	23.6	5.4	22.4	0.1	24.8	5.4	22.8	0.2	21.2	6.0	16.4	7.4
30					15.4	4.6	15.6	1.2	15.4	2.0			23.6	5.2	22.3	0.2	24.8	5.1	22.6	0.2				
32									15.0	1.7			23.6	3.9										
34													23.6	4.4										

Note: Units of measurements are: depth - feet, temperature - °C, and DO - mg/L.

Table A-3. Dissolved Oxygen and Temperature Observations at Station 3, 1996

	5/2		5/20		6/7		6/19		6/20		7/9		7/22		8/5		8/19		9/3		9/16		10/7	
Depth	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
0	11.7	10.4	22.2	8.2	19.7	9.0	24.4	8.6	27.3	9.4	25.6	8.5	23.2	4.9	25.6	7.5	24.6	5.4	26.8	9.7	21.3	9.0	16.6	11.4
1	11.7	10.5	22.3	8.2	19.7	9.0	24.4	8.6	27.0	9.6	25.6	8.6	23.2	4.8	25.6	7.5	24.6	5.4	26.7	9.7	21.3	9.0	16.6	11.4
2	11.7	10.5	22.3	8.2	19.7	9.0	24.4	8.6	25.6	9.8	25.6	8.6	23.2	4.9	25.6	7.4	24.5	5.4	25.7	9.2	21.3	9.0	16.6	11.5
3	11.7	10.5	22.3	8.2	19.7	9.0	24.4	8.6	25.2	10.0	25.6	8.6	23.2	4.8	25.6	7.4	24.5	5.3	25.6	8.7	21.3	8.9	16.6	11.6
4			22.2	8.1	19.7	8.9	24.3	8.6	24.9	10.0	25.6	8.6	23.2	4.8	25.6	7.3	24.5	5.3	25.5	7.9	21.4	8.9	16.6	11.6
5			22.2	8.0	19.7	8.9	24.2	8.6	24.8	9.7	25.6	8.6	23.2	4.8	25.6	7.3	24.5	5.3	25.5	7.5	21.4	8.9	16.6	11.7
6			22.2	7.9	19.7	8.8	24.2	8.6	24.7	9.3	25.6	8.6	23.2	4.7	25.5	7.2	24.5	5.3	25.4	7.5	21.4	8.9	16.6	11.7
7			22.2	7.1	19.7	8.8	24.0	6.6	24.6	8.6	25.6	8.5	23.2	4.8	25.5	6.4	24.4	5.3	25.4	7.6	21.4	8.9	16.6	11.7
8					19.6	8.7	24.0	6.6	24.0	7.4	25.6	8.5	23.2	4.8	25.2	5.1	24.4	5.3	25.3	7.6	21.3	8.9	16.6	11.8
9					19.6	8.7	23.9	6.1	23.1	5.8	25.6	8.5	23.2	4.4	25.0	5.1	24.4	5.3	25.1	5.8	21.3	8.8	16.6	11.0
10					19.5	8.7	23.9	5.9	22.6	5.2	25.6	8.5	23.1	4.5	24.9	4.2	24.4	5.3	24.8	5.1	21.3	8.8	16.4	10.5
11					19.2	7.3	21.1	5.0	21.8	4.7	25.6	8.4	22.9	3.6	24.6	2.0	24.4	5.3			21.0	5.2	16.3	7.8
12					18.2	7.1	20.8	4.3	20.3	3.2	25.6	8.3	22.2	3.0	24.5	0.9					20.9	4.7	16.0	6.4
13					18.1	7.1	20.4	3.6	19.8	3.2	25.4	8.1	22.2	2.8										
14							20.0	3.5	19.2	2.1			22.2	2.3										

Note: Units of measurements are: depth - feet, temperature - °C, and DO - mg/L.

Table A-4. Dissolved Oxygen and Temperature Observations at Station 1, 1997

	4/22		5/6		5/20		6/5		6/17		6/23		7/8		7/22		8/11		8/23		9/8		9/22		10/6	
Depth	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
0	11.3	10.3	12.5	9.5	15.7	7.9	18.1	17.6	22.3	10.6	24.8	10 .1	23.9	9.0	26.1	8.3	24.8	5.7	23.4	6.7	24.4	10.4	21.9	7.2	20.0	8.0
2	11.1	11.3	12.0	9.6	15.3	8.0	17.6	19.7	22.3	10.6	24.7	10.2	23.9	9.0	26.2	7.9	24.8	5.7	23.4	6.7	24.2	10.4	22.1	7.1	20.0	8.1
4	11.1	11.7	12.0	9.6	15.3	7.8	17.3	20+	22.2	10.6	24.7	10.2	23.9	9.0	26.2	7.9	24.8	5.7	23.4	6.7	24.1	10.4	22.0	7.1	19.9	8.1
6	11.1	11.7	11.9	9.7	15.2	7.8	17.0	20+	22.1	10.6	24.4	10.4	23.7	8.8	26.2	7.9	24.7	5.6	23.4	6.6	23.9	10.0	22.0	7.1	19.8	8.1
8	11.0	11.4	11.9	9.7	15.1	7.5	16.9	20+	22.1	10.6	23.8	10.6	23.6	8.8	26.2	7.9	24.7	5.5	23.3	6.4	23.5	9.4	22.0	7.1	19.8	8.0
10	11.0	11.9	11.9	9.7	15.1	7.5	16.8	20+	22.0	10.6	23.3	10.5	23.6	8.7	26.1	4.5	24.7	5.4	23.2	6.3	23.3	8.8	22.0	7.0	19.7	7.9
12	10.9	11.1	11.8	9.7	15.1	7.3	16.7	20+	21.9	10.6	22.7	10.1	23.6	8.7	25.4	3.4	24.7	54	23.2	6.2	23.1	8.1	22.0	7.0	19.7	7.9
14	10.9	11.1	11.8	9.8	15.0	7.4	16.7	20+	21.7	10.6	22.0	9.4	23.5	8.5	25.2	2.8	24.7	5.4	23.2	6.2	23.0	6.8	22.0	7.0	19.7	7.9
16	10.8	10.7	11.8	9.7	14.9	7.3	16.7	20+	20.8	10.8	21.6	9.2	23.2	7.6	25.1	2.6	24.7	5.3	23.2	6.2	22.8	6.3	22.0	7.0	19.7	7.8
18	10.4	10.4	11.8	9.7	14.8	7.2	16.4	20+	18.5	10.6	21.1	8.6	23.0	6.6	24.8	2.1	24.7	5.3	23.2	6.2	22.8	6.2	22 0	6.9	19.7	7.7
20	9.7	9.5	11.8	9.7	14.7	8.4	16.3	20+	17.8	9.4	22.6	8.3	22.9	6.0	24.6	2.3	24.7	5.2	23.2	6.2	22.7	6.1	22.0	6.9	19.7	7.7
22	9.2	9.4	11.8	9.7	14.6	8.3	16.3	20+	17.2	7.9	19.6	8.4	22.8	5.8	24.3	1.4	24.7	5.2	23.2	6.2	22.6	5.7	22.0	6.9	19.7	7.7
24	8.8	8.6	11.7	9.4	14.5	8.3	16.2	20+	16.5	6.2	18.3	7.7	22.7	5.3	24.0	1.1	24.7	5.2	23.2	6.2	22.6	5.6	22.0	6.9	19.7	7.7
26	8.7	8.4	11.7	9.3	14.5	8.2	16 .1	20+	16.1	4.1	17.2	5.6	22.5	4.0	23.6	0.5	24.7	5.3	23.2	6.2	22.5	5.4	22.0	69	197	7.8
28	8.6	8.5	11.7	9.3	14.1	8.0	15.9	20+	15.6	3.3	16.4	3.7	22.1	2.5	23.2	0.3	24.7	5.3	23.2	6.2	22.5	5.3	22.0	6.9	19.7	7.9
30	8.6	8.4	11.7	9.3	13.9	7.5	15.6	19.8	15.4	2.4	15.9	2.2	20.3	1.4	22.9	0.2	24.7	5.2	23.1	6.1	22.5	5.1	22.0	7.0	19.6	7.7
32	8.6	8.1	11.7	9.3	13.9	7.4	15.4	18.8	14.9	1.3	15.5	1.6	18.2	0.5	21.6	0.2	24.0	3.0	23.1	6.1	22.4	5.0	22.0	7.1	19.5	6.3
34	8.5	8.0	11.6	9.2	13.9	7.4	15.2	18.2	14.8	1.1	15.1	0.4	16.2	0.3	18 .5	0.2	22.6	0.4	23.0	3.5	22.2	4.0	22.0	7,0	19.5	5.4
36	8.5	7.9	11.5	9.1	13.8	7.2	15.0	15.8	14.6	0.6	14.6	0.3	15.0	0.2	15.7	0.2	16.4	0.3	21.3	0.4	21.7	1.8	22.0	7.0	19.4	5.1
38	8.3	7.6	11.0	8.5	13.8	7.1	14.4	14.1	14.4	0.2	14.3	0.3	14.1	0.2	14.6	0.2	15 .1	0.2	17.2	0.3	18.6	0.0	22.0	7.0	19.3	3.5
40	8.2	7.3	10.8	8.2	13.8	7.0	14 .1	12.2	14 .1	0.2	14 .1	0.3	13.9	0.2	13.9	0.2	14.3	0.2	153	0.3	15.7	0.0	22.0	7.0	19.0	1.7
42	8.1	7.2	9.9	5.5	13.8	6.9	13.9	11.9	13.7	0.2	13.8	0.2	13.8	0.2	13.7	0.2	13.7	0.2	13.6	0.3	14.5	0.0	22.0	7.1	18.1	0.3
44	8.0	6.6	9.3	5.2	13.8	6.9	13.2	5.6	13.7	0.2	13.6	0.2	13.4	0.2	13.3	0.2	13.3	0.2	13.3	0.3	13.5	0.0	22.0	7.1	15.6	0.2
46	8.0	5.6	9.0	3.6	13.8	6.8	12 .6	1.5	13.1	0.1	13.4	0.2	13.2	0.2	13.0	0.2	13.0	0.2	13.1	0.3	13.0	0.0	22.0	7.1		
48			9.0	2.9											13.0	0.2	12.8	02	12.9	0.3	12.9	0.0	22.0	7.0		

Note: Units of measurements are: depth - feet, temperature - °C, and DO - mg/L.

Table A-5. Dissolved Oxygen and Temperature Observations at Station 2, 1997

	4/22		5/6		5/20		6/5		6/17		6/23		7/8		7/22		8/11		8/23		9/8		9/22		10/6	
Depth	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
0	10.4	10.1	12.6	10.0	15.5	9.4	17.9	9.7	22.8	10.5	26.3	9.5	24.6	9.1	25.7	7.0	24.7	5.3	23.6	7.0	24.3	10.3	21.9	6.4	20.3	9.3
2	10.3	10.6	12.6	10.0	15.5	9.4	17.7	10.3	22.6	10.5	26.3	9.5	24.6	9.2	25.7	6.9	24.6	5.2	23.5	6.7	23.6	9.7	21.9	6.4	20.3	9.3
4	10.2	108	12.5	10.0	15.5	9.4	17.3	9.3	22.2	10.6	26.2	9.3	24.5	9.1	25.7	6.9	24.6	5.2	23.3	6.5	23.5	9.6	21.9	6.3	20.3	9.3
6	9.9	10.9	125	10.0	15.5	9.3	16.8	9.6	21.9	10.7	25.7	9.7	24.5	9.1	25.7	6.9	246	5.2	23.2	6.4	23.2	8.8	21.9	6.3	20.2	93
8	9.7	10.8	12.3	10.0	13.3	9.1	16.8	11.1	21.6	10.7	24.8	9.9	24.5	9.2	25.7	6.8	24.6	5.2	23.2	6.4	23.1	8.2	21.9	6.0	20.1	9.2
10	9.6	10.3	12.2	10.0	15.2	9.0	16.7	13.8	21.4	10.8	23.6	9.7	24.5	9.2	23.6	64	246	5.2	23.2	6.3	23 1	7.8	21.9	5.9	19.9	9.1
12	9.6	10.2	12.2	10.0	15.1	8.9	167	17.0	20.8	10.8	22.8	9.0	24.5	9.2	25.5	5.3	24.6	5.1	23.2	6.1	23.0	7.4	21.9	5.9	19.9	8.8
14	9.6	10.0	12.2	10.0	15.1	8.9	16.6	18.5	20.1	10.5	22.0	7.4	24.3	8.8	25.2	4.1	24.6	5.0	23.2	5.9	23.0	7.0	21.9	5.9	19.9	8.8
16	9.5	9.9	12.2	10.0	15.1	8.9	16.6	19.2	19.7	11.1	21.6	7.4	23.8	8.3	25.0	2.8	24.6	4.9	23.2	5.9	22.7	5.2	21.9	5.9	19.9	8.8
18	9.4	9.6	12.2	10.0	15.1	8.9	16.6	196	19.0	9.8	21.1	7.0	23.5	7.8	24.9	2.0	24.6	4.9	23.2	5.8	22.7	5.1	21.9	5.9	19.9	8.7
20	9.3	9.4	12.2	10.0	15.0	8.7	16.6	20+	17.9	7.1	20.7	6.3	23.3	7.0	24.8	1.5	24.6	4.9	23.1	5.7	22.6	5.0	21.9	5.9	19.9	8.7
22	9.2	9.3	12.2	10.0	14.4	7.5	16.5	20+	17.2	5.9	19.6	3.4	23.1	6.3	24.7	0.2	24.6	4.7	23.1	5.7	22.6	4.6	21.9	5.9	19.9	8.7
24	9.0	8.6	12.2	10.0	14.2	7.4	16.2	20+	16.8	4,5	19.0	3.9	23.0	5.9	24.0	0.2	24.6	4.7	23.1	5.7	22.5	4.3	21.9	5.9	19.8	8.7
26	8.9	8.5	12.2	9.9	14.2	7.4	16.1	20+	16.4	3.7	17.6	3.6	22.5	4.0	23.6	0.2	24.6	4.7	23.1	5.3	22.4	4.0	21.9	5.9	19.8	8.6
28	8.8	83	12.2	9.8	14.1	74	16.0	19.6	16.1	2.6	16.7	0.9	21.9	12	23.4	0.2	24.6	4.7	23.0	5.0	22.4	4.0	21.9	5.9	19.8	8.5
30	8.7	8.0	12.1	9.7					15.7	2.0	16.2	0.5	21.7	0.7	22.8	0.2	24.6	4.7	22.9	4.3	22.3	3.9	21.8	6.0	19.8	8.4
32	8.6	7.6							15.6	1.0	15.5	0.3					24.5	4.3	22.9	3.7	22.3	3.4	21.8	6.1	19.8	7.7
34	8.6	7.4									15.5	0.3														

Note: Units of measurements are: depth - feet, temperature - °C, and DO - mg/L.

Table A-6. Dissolved Oxygen and Temperature Observations at Station 3, 1997

Depth	4/22		5/6		5/20		6/5		6/17		6/23		7/8		7/22		8/11		8/23		9/8		9/22		10/6	
	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO	Temp	DO
0	11.4	10.9	13.3	11.1	16.8	10.4	18.3	19.7	24.1	10.5	27.1	9.4	24.7	11.2	25.8	4.9	24.5	7.3	23.6	10.2	24.1	12.7	21.9	9.0	20.7	10.9
1	11.4	10.8	13.3	11.1	16.8	10.4	18.3	20+	24.0	10.6	27.0	9.5	24.7	11.2	25.8	4.9	24.5	7.1	23.6	10.3	24.1	12.8	21.9	9.1	20.7	10.9
2	11.3	108	13.3	11.1	16.8	10.4	17.5	20+	23.9	10.7	26.8	10.0	24.7	11.1	25.8	4.9	24.5	7.0	23.6	10.2	23.3	10.8	21.9	9.1	20.7	10.9
3	11.3	109	13.2	11.1	168	10.7	17.6	20+	23.8	10.8	26.6	10.3	24.6	11.1	258	4.8	24.4	66	23.6	9.9	23.1	9.5	21.8	9.0	20.7	10.9
4	11.3	10.6	13.1	11.0	16.8	10.3	17.3	20+	23.6	10.8	25.8	10.3	24.6	10.7	258	4.9	24.3	6.1	24.4	9.4	23.0	9.0	21.6	8.4	20.6	10.6
5	112	10.4	13.1	11.0	16.8	10.3	17.3	20+	22.9	11.3	24.7	10.4	24.3	9.3	25.8	4.9	24.3	6.1	24.3	8.8	23.0	8.5	21.6	8.4	20.1	9.6
6	11.2	106	13.0	110	16.8	10.2	17.2	20+	22.3	11.0	24.3	10.1	24.2	9.2	25.8	4.9	24.3	6.1	23.1	8.2	23.0	8.2	21.5	8.2	20.0	9.1
7	11.1	10.8	12.9	10.7	16.7	10.4	17.2	20+	22.3	11.0	23.8	9.4	23.8	6.0	25.8	4.9	242	65	23.1	8.1	23.0	8 1	21.5	8.0	19.9	8.4
8	11.1	108	12.9	10.6	16.7	9.6	17.2	20+	22.2	11.0	23.5	8.4	23.7	5.4	25.8	4.6	24.2	6.7	23.1	8.1	22.8	7.5	21.5	7.9	19.8	83
9	11.1	106	12.9	10.5	16.7	9.5	17.1	20+	22.0	10.8	23.1	7.3	23.6	5.3	25.8	4.5	24.2	6.6	23.0	8.1	22.8	7.1	21.5	7.8	19.8	8.2
10	11.1	107	12.9	10.5	16.7	9.5	17.1	20+	21.8	10.6	22.7	5.8	23.6	5.1	258	4.5	24.2	6.5	23.0	8.2	22.7	6.4	21.4	7.7	19.8	7.6
11	11.0	10.6	12.9	10.3	15.9	9.4	17.0	20+	21.6	10.4	22.5	5.6	23.5	4.4	25.8	3.9	24.2	5.9	23.0	8.3	22.7	6.0	214	7.7	19.6	5.8
12		12.9		10.3	15.7	9.2	16 .7	20+	20.9	9.2	22.2	5.3	23.2	2.8	25.7	3.4	24.1	5.7	23.0	8.3	22.6	5.3	21.4	7.7	19.4	5.3
13			12.8	10.2	15.6	9.0	16.6	20+	20.5	8 1	21.8	5.0	23.2	2.0	25.6	2.5	24.1	5.1	22.9	7.7	22.4	4.1	21.4	7.6		
14																			22.9	7.5			21.3	7.3		

Note: Units of measurements are: depth - feet, temperature - °C, and DO - mg/L.

Appendix B.
Percent Saturation Values

Table B-l. Percent Saturation Values at Station 1,1996

Depth, feet	*5/2*	*5/20*	*6/7*	*6/19*	*6/20*	*7/9*	*7/22*	*8/5*	*8/19*	*9/3*	*9/16*	*10/7*
0	95	99	107	110	111	101	80	131	74	113	72	83
2	96	99	107	110	115	102	80	131	75	115	72	83
4	95	99	107	109	119	102	80	130	75	116	72	82
6	96	99	107	108	118	102	81	132	75	123	73	82
8	96	99	106	110	119	74	81	132	73	131	73	82
10	96	99	98	111	113	66	80	130	73	89	73	81
12	96	99	95	104	101	58	80	127	73	67	74	81
14	96	97	94	103	92	52	80	96	73	57	74	80
16	96	95	92	67	85	44	80	86	73	37	74	78
18	96	93	84	60	74	39	80	79	71	26	74	77
20	97	87	78	55	70	27	80	17	70	18	75	76
22	97	83	75	53	63	15	75	2	70	7	75	76
24	97	80	72	52	56	10	50	1	71	5	75	75
26	96	71	68	48	50	3	11	1	70	5	75	74
28	96	66	66	43	48	2	1	1	4	5	75	74
30		53	66	35	40	2	1	1	2	5	74	74
32		53	62	26	35	2	1	1	2	4	73	74
34		37	56	11	29	2	1	2	2	4	73	73
36			53	5	21	2	1	2	2	4	73	73
38			35	2	6	2	1	2	2	4	73	70
40			24	2	5	2	1	2	2	4	71	40
42						2	1	2	2	4	73	2
44							1	2			68	2

Table B-2. Percent Saturation Values at Station 2, 1996

Depth, feet	*5/2*	*5/20*	*6/7*	*6/19*	*6/20*	*7/9*	*7/22*	*8/5*	*8/19*	*9/3*	*9/16*	*10/7*
0	100	99	102	107	119	120	68	124	72	123	77	96
2	100	99	102	107	119	121	68	124	72	123	77	96
4	100	99	102	105	119	121	67	125	72	126	77	95
6	96	99	102	106	119	121	67	125	72	107	77	94
8	96	99	101	106	110	121	67	125	71	92	74	92
10	95	98	101	97	92	121	67	125	71	84	72	88
12	95	97	101	74	83	101	67	125	70	75	72	85
14	95	96	100	79	73	82	67	123	70	55	64	85
16	95	94	100	63	64	74	66	110	70	46	64	86
18	95	94	97	53	63	69	64	81	70	32	66	87
20		86	69	46	59	44	64	22	68	17	64	88
22		61	56	37	40	43	64	2	66	4	61	85
24			54	29	34	13	64	2	66	2	70	79
26			54	28	27	9	65	1	66	2	69	79
28			47	15	24	2	64	1	66	2	68	76
30			46	12	20		62	2	62	2		
32					17		46					
34							53					

Table B-3. Percent Saturation Values at Station 3, 1996

Depth, feet	5/2	5/20	6/7	6/19	6/20	7/9	7/22	8/5	8/19	9/3	9/16	10/7
0	96	95	99	104	120	105	58	93	66	123	102	118
1	97	95	99	104	122	106	57	93	66	123	102	118
2	97	95	99	104	121	106	58	92	65	114	102	119
3	97	95	99	104	123	106	57	92	64	108	101	120
4		94	98	104	122	106	57	90	64	98	101	120
5		93	98	104	118	106	57	90	64	93	101	121
6		92	97	104	113	106	56	89	64	92	101	121
7		82	97	79	104	105	57	79	64	94	101	122
8			96	79	89	105	57	63	64	93	101	121
9			96	73	68	105	52	62	64	71	100	114
10			95	71	61	105	53	51	64		100	107
11			80	57	54	104	42	24			59	80
12			76	48	36	103	35	10			53	65
13			76	40	35	100	32					
14				39	23		27					

Table B-4. Percent Saturation Values at Station 1, 1997

Depth, feet	*4/22*	*5/6*	*5/20*	*6/5*	*6/17*	*6/23*	*7/8*	*7/22*	*8/11*	*8/23*	*9/8*	*9/22*	*10/6*
0	94	89	79	188	123	123	108	104	69	79	126	83	89
2	103	89	80	208	123	124	108	99	69	79	125	82	90
4	107	89	78	210+	123	124	108	99	69	79	125	82	90
6	107	90	78	208	123	126	105	99	68	78	120	82	89
8	104	90	75	208	123	127	105	99	67	76	112	82	88
10	108	90	75	207	122	124	104	56	66	74	104	81	87
12	101	90	73	207	122	130	104	42	66	73	96	81	87
14	101	91	74	207	122	108	101	34	66	73	80	81	87
16	97	90	73	207	122	105	90	32	64	73	74	81	86
18	93	90	71	206	114	97	78	26	64	73	73	80	85
20	84	90	83	205	100	97	70	27	63	73	71	80	85
22	82	90	82	205	83	92	68	17	63	73	67	80	85
24	74	87	82	205	64	82	62	13	63	61	65	80	85
26	72	86	81	204	42	59	47	6	64	73	63	80	86
28	73	86	78	203	33	38	29	4	64	73	62	80	87
30	72	86	73	200	24	22	16	2	63	72	59	81	85
32	69	86	72	189	13	16	5	2	36	72	58	82	69
34	68	85	72	182	11	4	3	2	5	41	47	81	59
36	68	84	70	157	6	3	2	2	3	5	21	81	56
38	65	77	69	139	2	3	2	2	2	3	0	81	38
40	62	74	68	119	2	3	2	2	2	3	0	81	18
42	61	49	67	116	2	2	2	2	2	3	0	82	3
44	56	45	67	54	2	2	2	2	2	3	0	82	2
46	47	31	66	14	1	2	2	2	2	3	0	82	
48		25						2	2	3	0	81	

Table B-5. Percent Saturation Values at Station 2,1997

Depth, feet	*4/22*	*5/6*	*5/20*	*6/5*	*6/17*	*6/23*	*7/8*	*7/22*	*8/11*	*8/23*	*9/8*	*9/22*	*10/6*
0	90	94	95	103	123	119	110	87	64	83	124	74	104
2	95	94	95	109	123	119	117	86	63	80	115	74	104
4	96	94	95	97	123	119	110	86	63	77	114	73	104
6	96	94	94	100	123	120	110	86	63	76	104	73	104
8	95	94	91	115	122	121	111	84	63	76	97	69	102
10	90	93	90	143	123	115	111	79	63	74	92	68	101
12	90	93	89	176	122	105	111	65	62	72	87	68	97
14	88	93	89	191	117	85	106	50	61	70	82	68	97
16	87	93	89	198	122	85	99	34	59	70	61	68	97
18	84	93	89	202	106	79	93	24	59	69	60	68	96
20	82	93	87	202	75	71	83	18	59	67	58	68	96
22	81	93	74	206+	62	37	74	2	57	67	54	68	96
24	74	93	72	205+	47	42	69	2	57	67	50	68	96
26	73	93	72	204+	38	38	47	2	57	62	47	68	95
28	72	92	72	200+	27	9	14	2	57	59	47	68	94
30	69	90			20	5	8	2	57	51	45	70	93
32	65				10	3			52	43	39	70	85
34	63					3							

Table B-6. Percent Saturation Values at Station 3, 1997

Depth, feet	*4/22*	*5/6*	*5/20*	*6/5*	*6/17*	*6/23*	*7/8*	*7/22*	*8/11*	*8/23*	*9/8*	*9/22*	*10/6*
0	100	106	108	211	126	120	136	61	88	121	153	104	123
1	99	106	108	214	127	121	136	61	86	123	154	105	123
2	99	106	108	210	128	127	135	61	85	121	128	105	123
3	100	106	111	210	129	130	135	60	80	118	112	104	123
4	97	105	107	210	129	128	130	61	74	114	106	96	119
5	95	105	107	210	133	126	112	61	74	106	100	96	107
6	97	105	106	209	128	122	110	61	74	97	96	94	101
7	98	102	108	209	128	112	72	61	78	96	95	91	93
8	98	101	99	209	127	100	64	57	81	96	88	90	92
9	97	100	98	209	125	86	63	56	79	95	83	89	91
10	97	100	98	209	122	68	61	56	78	96	75	88	84
11	96	98	96	208	119	65	52	48	71	98	70	88	64
12		98	93	207	103	61	33	42	69	98	62	88	58
13		97	91	206	91	57	24	31	61	90	48	87	
14										88		83	

Appendix C.
Physical and Chemical Quality Characteristics

Table C-1. Water Quality Characteristics at Station 1, Surface, 1996

Parameter	*5/20*	*6/7*	*6/19*	*6/20*	*7/9*	*7/22*	*8/5*	*8/19*	*9/3*	*9/16*	*10/7*
Secchi readings (inches)	30	38	103	90	59	56	52	58	44	41	39
Turbidity, NTU	1 1	1 0		3 2	2 5		5	5		4 6	5
pH (units)	8.48	8.41	8.61	8.64	8.34	8.36	8.56	8.25	8.59	8.24	8.39
Total alkalinity	192	184	176	180	160	166	162	172	162	172	176
Conductivity, (imho/cm	536	-	534	556	499	502	470	501	478	491	484
Total suspended solids	6	5	1	1	3	4	7	6	6	4	6
Volatile suspended solids	1	2	0	1	2	2	2	4	5	3	1
Dissolved solids	-	314	313	328	270	292	290	326	272	286	268
Total phosphate-P	0.02	-	-	0.04	0.02	0.04	0.04	0.03	0.03	0.03	0.03
Dissolved phosphate-P	-	-	-	0.02	0.01	0.01	0.00	0.01	0.01	0.01	<0.01
Nitrate & Nitrite-N	-	-	-	5.20	5.19	4.62	3.78	3.14	2.39	1.84	1.39
Ammonia-N	-	-	-	0.07	0.05	0.03	0.02	0.05	0.13	0.14	0.08

Note: Values in mg/L unless otherwise indicated.

Table C-2. Water Quality Characteristics at Station 2, Surface, 1996

Parameter	*5/2*	*5/20*	*6/7*	*6/19*	*7/9*	*7/22*	*8/5*	*8/19*	*9/3*	*9/16*	70/7
Secchi readings (inches)	22	30	28	91	57	36	48	48	44	33	37
Turbidity, NTU	15	13	11	4	5	6	4	6	6	9	6
pH (units)	8.47	8.48	8.48	8.59	8.52	8.16	8.56	8.17	8.64	8.22	8.53
Total alkalinity	188	193	171	180	165	173	167	173	162	168	174
Conductivity, umho/cm	549	540	526	540	494	503	478	502	474	489	485
Total suspended solids	19	8	6	1	4	5	8	8	8	7	7
Volatile suspended solids	3	1	2	1	2	1	3	4	6	4	2
Dissolved solids	329	322	305	323	282	314	300	336	272	282	264
Total phosphate-P	0.05	0.04	0.06	0.02	0.04	0.04	0.29	0.03	0.03	0.04	0.03
Dissolved phosphate-P	0.01	0.01	0.03	0.01	<0.01	0.01	<0.01	0.01	0.01	0.01	<0.01
Nitrate & Nitrite-N	2.63	4.05	5.21	5.74	4.50	4.50	3.46	2.91	2.34	1.65	1.46
Ammonia-N	0.02	0.06	0.07	0.07	0.06	0.06	0.02	0.07	0.15	0.13	0.09

Note: Values in mg/L unless otherwise indicated.

Table C-3. Water Quality Characteristics at Station 2, Bottom, 1996

Parameter	*5/2*	*5/20*	*6/7*	*6/19*	*7/9*	*7/22*	*8/5*	*8/19*	*9/3*	*9/16*	*10/7*
Secchi readings (inches)	-	-	-	-	-	-	-	-	-	-	-
Turbidity, NTU	29	16	39	8	12	11	9	22	6	38	19
pH (units)	8.47	8.41	7.98	7.92	7.86	8.16	7.76	8.13	8.64	8.18	8.60
Total alkalinity	190	193	181	186	185	171	176	173	162	168	176
Conductivity, µmho/cm	544	545	539	559	534	504	514	507	474	474	480
Total suspended solids	33	12	28	3	10	10	11	28	8	36	18
Volatile suspended solids	3	1	5	0	2	2	2	8	6	9	4
Dissolved solids	331	328	312	307	322	328	324	336	268	278	260
Total phosphate-P	0.06	0.05	0.12	0.10	0.05	0.04	0.04	0.08	0.03	0.10	0.05
Dissolved phosphate-P	0.01	0.01	0.05	0.06	0.01	0.01	0.01	0.01	0.03	0.02	<0.01
Nitrate & Nitrite-N	2.65	4.49	6.81	6.04	4.92	4.43	3.16	2.86	2.29	1.29	1.18
Ammonia-N	0.02	0.07	0.14	0.08	0.12	0.07	0.17	0.08	0.14	0.12	0.13

Note: Values in mg/L unless otherwise indicated.

Table C-4. Water Quality Characteristics at Station 3, Surface, 1996

Parameter	*5/2*	*5/20*	*6/7*	*6/19*	*7/9*	*7/22*	*8/5*	*8/19*	*9/3*	*9/16*	*10/7*
Secchi readings (inches)	22	13	19	62	28	14	19	15	32	15	22
Turbidity, NTU	25	28	16	4	9	21	9	25	8	17	8
pH (units)	8.50	8.48	8.32	8.49	8.44	8.05	8.30	8.12	8.71	8.58	8.82
Total akalinity	217	198	179	187	177	181	180	180	170	168	175
Conductivity, µmho/cm	647	588	536	556	507	507	506	509	486	481	476
Total suspended solids	31	34	12	3	10	12	12	26	10	19	10
Volatile suspended solids	6	6	2	1	3	2	5	8	6	6	3
Dissolved solids	390	351	318	331	312	282	340	336	288	278	260
Total phosphate-P	0.08	0.08	0.09	0.05	0.07	0.08	0.07	0.09	0.06	0.08	0.05
Dissolved phosphate-P	0.01	0.01	0.04	0.03	0.02	0.03	0.01	0.02	0.02	0.02	0.02
Nitrate & Nitrite-N	5.13	7.83	7.78	6.43	4.14	3.28	2.69	2.10	1.64	1.39	1.06
Ammonia-N	0.02	0.02	0.12	0.10	0.30	0.09	0.04	0.13	0.23	0.12	0.03

Note: Values in mg/L unless otherwise indicated.

Table C-5. **Water Quality Characteristics at Station 1, Surface, 1997**

Parameter	*4/22*	*5/6*	*5/20*	*6/5*	*6/17*	*6/23*	*7/8*	*7/23*	*8/12*	*8/25*	*9/8*	*9/22*	*10/6*
Secchi readings (inches)	31	39	73	98	101	109	58	61	69	54	72	63	48
Turbidity, NTU	9	8	3	2	1	2	2	2	4	4	4	4	5
pH (units)	8.61	8..28	8.42	8.57	8.61	8.59	8.58	8.58	8.22	8.25	8.62	8.35	8.34
Total alkalinity	170	166	174	175	173	169	168	147	157	147	156	158	156
Conductivity, µmho/cm	526	526	534	530	520	513	522	466	492	500	472	473	486
Total suspended solids	9	7	3	4	3	5	4	6	4	2	2	7	5
Volatile suspended solids	5	1	3	1	2	2	2	2	2	1	2	4	4
Dissolved solids	276	296	294	320	312	330	330	254	292	296	279	290	270
Total phosphate-P	0.05	0.03	0.02	0.02	0.01	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03
Dissolved phosphate-P	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	0.01
Nitrate & Nitrite-N	3.36	3.36	3.35	3.35	3.36	2.94	2.92	1.71	1.33	0.97	0.83	0.59	0.51
Ammonia-N	0.10	0.09	0.12	0.12	0.08	<0.02	<0.02	0.03	0.10	0.10	0.02	0.04	<0.02

Note: Values in mg/L unless otherwise indicated.

Table C-6. Water Quality Characteristics at Station 2, Surface, 1997

Parameter	*4/22*	*5/6*	*5/20*	*6/5*	*6/17*	*6/23*	*7/8*	*7/23*	*8/12*	*8/25*	*9/8*	*9/22*	*10/6*
Secchi readings (inches)	34	33	54	81	105	84	47	63	37	38	50	31	39
Turbidity, NTU	8	9	4	3	1	2	3	2	8	6	4	9	7
pH (units)	8.50	8.29	8.37	8.56	8.60	8.58	8.62	8.42	8.18	8.26	8.71	8.25	8.47
Total alkalinity	172	169	178	179	173	171	165	153	156	157	155	159	160
Conductivity, µmho/cm	528	536	542	537	504	523	518	477	487	488	470	481	487
Total suspended solids	8	6	3	2	3	5	7	5	8	4	5	12	8
Volatile suspended solids	4	2	0	1	1	5	2	2	4	1	3	6	5
Dissolved solids	284	292	312	352	316	312	334	264	286	286	279	276	272
Total phosphate-P	0.04	0.03	0.03	0.02	0.01	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04
Dissolved phosphate-P	0.02	<0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01
Nitrate & Nitrite-N	3.62	3.46	3.46	3.31	3.19	2.90	2.38	1.65	1.11	0.92	0.67	0.63	0.51
Ammonia-N	0.06	0.11	0.12	0.04	<0.02	<0.02	<0.02	0.08	0.15	0.13	0.02	0.05	<0.02

Note: Values in mg/L unless otherwise indicated.

Table C-7. Water Quality Characteristics at Station 2, Bottom, 1997

Parameter	*4/22*	*5/6*	*5/20*	*6/5*	*6/17*	*6/23*	*7/8*	*7/23*	*8/12*	*8/25*	*9/8*	*9/22*	*10/6*
Secchi readings (inches)	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity, NTU	15	19	6	6	2	40	6	5	7	43	-	11	32
pH (units)	8.25	8.29	8.26	8.43	7.96	7.85	8.03	7.89	8.18	8.03	-	8.23	8.34
Total alkalinity	170	169	175	179	184	193	177	177	140	157	-	157	160
Conductivity, µmho/cm	527	531	561	539	540	551	539	512	488	489	-	487	491
Total suspended solids	13	17	6	7	4	94	10	10	8	45	-	14	33
Volatile suspended solids	3	2	0	1	1	14	0	4	4	6	-	7	9
Dissolved solids	284	296	318	356	300	344	340	282	288	292	-	277	271
Total phosphate-P	0.06	0.05	0.04	0.03	0.02	0.12	0.04	0.06	0.04	0.08	-	0.04	0.07
Dissolved phosphate-P	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.03	0.01	<0.01	-	0.01	0.01
Nitrate & Nitrite-N	3.15	3.42	3.31	3.31	2.70	2.24	2.07	1.10	1.14	0.75	-	0.60	0.51
Ammonia-N	0.14	0.05	0.18	0.06	0.13	0.28	0.16	0.50	0.15	0.20	-	0.07	0.02

Note: Values in mg/L unless otherwise indicated.

Table C-8. Water Quality Characteristics at Station 3, Surface, 1997

Parameter	*4/22*	*5/6*	*5/20*	*6/5*	*6/17*	*6/23*	*7/8*	*7/23*	*8/12*	*8/25*	*9/8*	*9/22*	*10/6*
Secchi reading (inches)	24	28	36	44	55	49	35	33	26	29	41	29	36
Turbidity, NTU	9	11	8	5	2	3	5	5	10	10	8	8	6
pH (units)	8.58	8.34	8.44	8.57	8.59	8.57	8.67	8.13	8.38	8.72	8.92	8.50	8.67
Total alkalinity	176	174	186	188	189	181	158	156	152	156	155	157	162
Conductivity, µmho/cm	564	564	540	551	540	536	506	483	475	479	465	485	490
Total suspended solids	9	10	6	6	3	5	20	20	12	9	10	12	7
Volatile suspended solids	4	3	0	3	2	3	4	4	6	6	6	7	4
Dissolved solids	308	312	322	366	322	344	334	274	264	298	283	283	272
Total phosphate-P	0.05	0.04	0.04	0.03	0.02	0.03	0.06	0.07	0.07	0.07	0.06	0.06	0.04
Dissolved phosphate-P	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.05	0.01	0.01	0.01	0.01
Nitrate & Nitrite-N	5.26	4.25	4.22	3.42	3.04	2.53	1.72	1.25	0.76	0.66	0.65	0.37	0.26
Ammonia-N	0.07	0.04	0.04	0.06	0.03	<0.02	<0.02	0.19	0.06	0.01	0.02	<0.02	0.02

Note: Values in mg/L unless otherwise indicated.

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