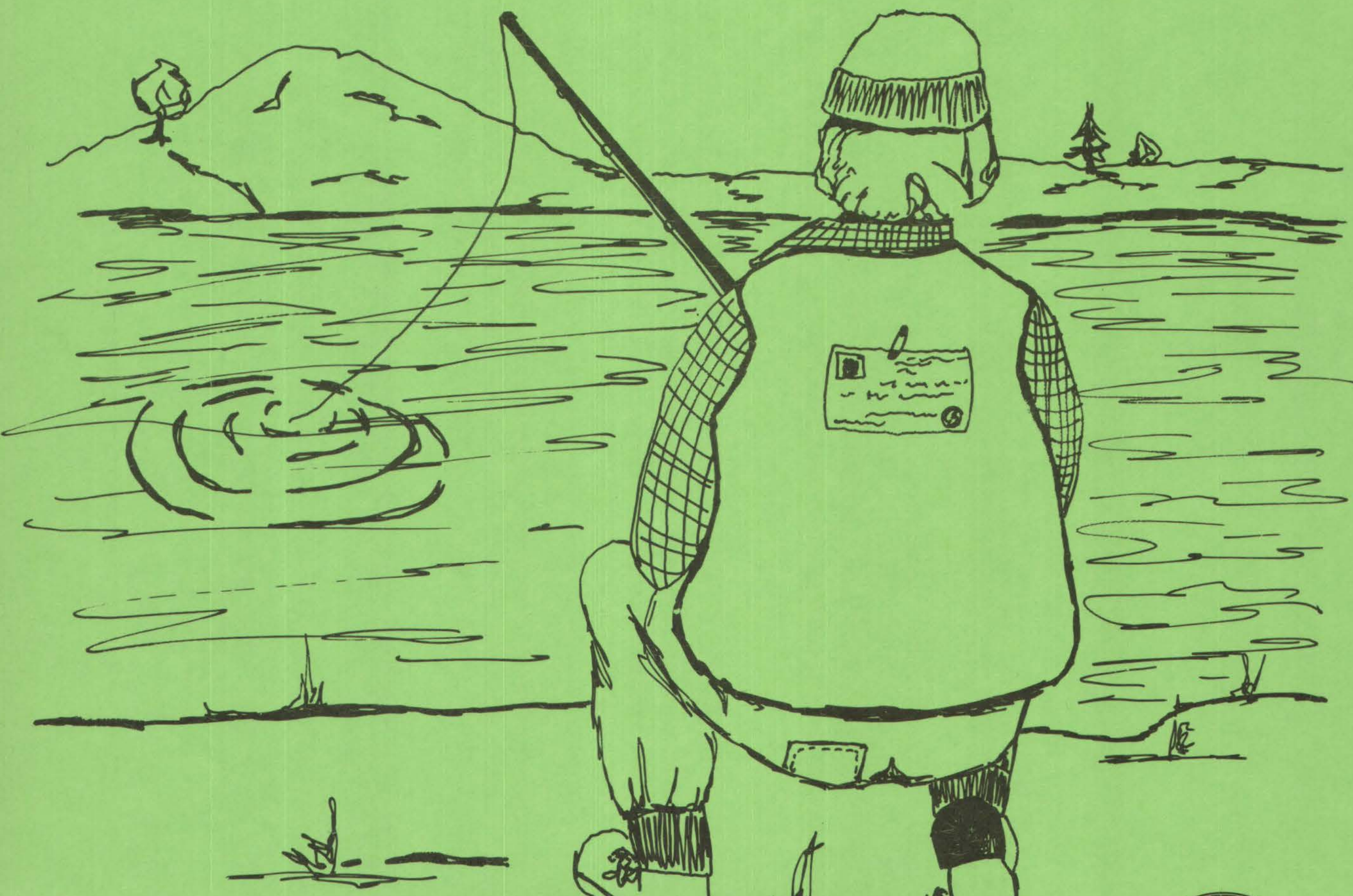
POSTIMPOUNDMENT SURVEY OF WATER-QUALITY CHARACTERISTICS OF RAYSTOWN LAKE, HUNTINGDON AND BEDFORD COUNTIES, PENNSYLVANIA

U.S. GEOLOGICAL SURVEY

WATER RESOURCES INVESTIGATION 78-42



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Water-quality data, collected from May 1974 to September 1976 at thirteen sites within Raystown Lake and in the inflow and outflow channels, define the water-quality characteristics of the lake water and the effects of impoundment on the quality of the lake outflow. Depth-profile measurements show Raystown Lake to be dimictic, with two overturn periods annually--one in the spring and one in the fall. Thermal stratification is well developed during the summer. Generally high concentrations of dissolved oxygen throughout the hypolimnion during thermal stratification, low phytoplankton concentrations, and small diel fluctuations of dissolved oxygen, pH, and specific conductance indicate that the lake is low in nutrients, or oligotrophic. Algal assays of surface samples indicate that orthophosphate was a growth-limiting nutrient. The diatoms (Chrysophyta) were the dominant phytoplankton group found throughout the study period. The lake waters contained very low populations of zooplankton. Fecal coliform and fecal streptococcus densities measured throughout the lake indicated no potentially dangerous areas for water-contact recreation. The most apparent effect that the impoundment had on water quality was the removal of nutrients, particularly orthophosphate, through phytoplankton uptake and sediment deposition.

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July 1978

UNITED STATES DEPARTMENT OF THE INTERIOR

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Factors for converting SI metric units to U.S. customary units

To convert from	To	Multiply by
millimeter (mm)	inch (in)	0.03937
meter (m)	foot (ft)	3.281
kilometer (km)	mile (mi)	0.6214
hectometer^2 (hm^2)	acre	2.471
kilometer^2 (km^2)	mile^2 (mi^2)	0.3861
hectometer^3 (hm^3)	acre-foot (acre-ft)	810.7
meter^3 per second (m^3/s)	foot^3 per second (ft^3/s)	35.31
degree Celsius (°C)	degree Fahrenheit (°F)	Temp°F = 1.8 temp°C+32

POSTIMPOUNDMENT SURVEY OF

WATER-QUALITY CHARACTERISTICS OF RAYSTOWN LAKE,

HUNTINGDON AND BEDFORD COUNTIES, PENNSYLVANIA

By Donald R. Williams

ABSTRACT

Water-quality data, collected from May 1974 to September 1976 at thirteen sites within Raystown Lake and in the inflow and outflow channels, define the water-quality characteristics of the lake water and the effects of impoundment on the quality of the lake outflow. Depth-profile measurements show Raystown Lake to be dimictic, with two overturn periods annually--one in the spring and one in the fall. Thermal stratification is well developed during the summer.

Generally high concentrations of dissolved oxygen throughout the hypolimnion during thermal stratification, low phytoplankton concentrations, and small diel fluctuations of dissolved oxygen, pH, and specific conductance indicate that the lake is low in nutrients, or oligotrophic. Minor vertical changes in pH were due mainly to variations in the carbon dioxide-bicarbonate-carbonate equilibrium. The comparatively low nutrient content and minimal littoral area tend to reduce the growth of nuisance aquatic vegetation. Algal assays of surface samples indicate that orthophosphate was a growth-limiting nutrient. The settling of fine sediment and a decrease in the phytoplankton biomass result in increasing water transparency from the head of the lake to the dam. Chemical analyses of the lake waters in contact with the bed material indicated no potentially toxic concentrations of metallic ions.

The diatoms (Chrysophyta) were the dominat phytoplankton group found throughout the study period. Green algae (Chlorophyta) and blue-green algae (Cyanophyta) were also found. The lake waters contained very low populations of zooplankton. Fecal coliform and fecal streptococcus densities measured throughout the lake indicated no potentially dangerous areas for water-contact recreation.

The most apparent effect that the impoundment had on water quality was the removal of nutrients, particularly orthophosphate, through phytoplankton uptake and sediment deposition. Measurable amounts of orthophosphate were present in 80 percent of the samples collected at the inflow, but only in 10 percent of the samples collected at the outflow. Although temperature, dissolved oxygen, and pH varied throughout the lake, their values at the outflow were very similar to those at the inflow to the lake.

INTRODUCTION

Purpose and Scope

This report is the postimpoundment evaluation of the quality of Raystown Lake and supplements the author's preimpoundment study (Williams, 1976). Selected physical, chemical, and biological characteristics of the lake were determined periodically, as was the effect of impoundment on stream quality immediately below the dam. Determinations of water temperature, dissolved oxygen, pH, specific conductance, alkalinity, and fecal coliform and fecal streptococcus bacteria counts were made in the field, and determinations of organic nitrogen, ammonium-nitrogen, nitrate-nitrogen, total orthophosphate as phosphorus, total phosphorus, total organic carbon (TOC), and metallic ion concentrations in the laboratory. Instantaneous discharges of inflow and outlfow were obtained at USGS gaging stations. Determinations of Secchi disc transparencies, algal growth potential (AGP), chlorophyll *a*, and plankton identification were made only at lake sites.

Background Information

Construction of Raystown Lake was authorized by the United States Flood Control Act of 1962. The dam was completed in October 1973, and the lake filled to its normal pool elevation (240 m) on March 6, 1975.

Raystown Dam is a rolled, earth and rockfill embankment 518 m long and 70 m high. A gated and an ungated spillway are near the right abutment. Four release levels in the gated section have inverts at elevations 223, 229, 233, and 234 m (spillway crest). A tunnel beneath the ungated spillway permits discharge from elevation 190 m.

The dam is regulated to reduce flooding downstream, to maintain minimum flows conducive to establishing and maintaining downstream fisheries, to provide a minimum outflow of 7.08 m^3/s, and to maintain pool levels in the lake conducive to general outdoor recreation use and esthetic values. An outflow of less than 7.08 m^3/s could result in significant adverse affects to the downstream aquatic community. Moderate drawdown in the lake may occur during many recreation seasons and as much as 2.4 m of drawdown can be expected once every 5 years.

Raystown Lake supports a variety of recreational activities, including boating, fishing, water skiing, hunting, camping, and swimming.

The elevation of the recreation pool of Raystown Lake is 240 m above mean sea level. This pool has a surface area of 3,360 hm^2, a shoreline of 190 km, and it extends 48 km upstream from the dam. The elevation of the flood-control pool is 247 m above mean sea level. It has a surface area of 4,370 hm^2 and extends 55 km upstream from the dam. The total storage capacity of the lake at recreation-pool elevation and at flood-control-pool elevation is 634 hm^3 and 937 hm^3, respectively.

DESCRIPTION OF STUDY AREA

Raystown Lake is on the Raystown Branch Juniata River in Huntingdon and Bedford Counties, south-central Pennsylvania. (See fig. 1.) The dam is about 6.4 km southeast of the town of Huntingdon and 8.8 km above the confluence of the Raystown Branch with the Juniata River. The dam controls the drainage from 2490 km^2, most of which is wooded and only a small part of which is cultivated. In addition to the Raystown Branch, seven other tributaries to the lake have perennial flow. Hawns Run, James Creek, Coffee Run, and Shy Beaver Creek flow into the west side of Raystown Lake at 6.4, 30.6, 40.2, and 44.2 km, respectively, above the dam. Great Trough Creek, Tatman Run, and Shoup Run flow into the east side of Raystown Lake at 31.4, 32.2, and 48.3 km, respectively, above the dam.

Raystown Lake is in the Valley and Ridge section of the Appalachian Highlands physiographic province. Raystown Lake is bounded by the Terrace Mountain range on the east and the Allegrippis Ridge on the west. The lake is underlain principally by Devonian shale and sandstone. The easternmost bay areas of the lake occasionally cross onto the Mississippian Pocono Sandstone. The dendritic embayments on the western shore overlie Lower Devonian shale and the Helderberg Formation.

Soils of the Raystown Lake area are predominantly of the Barbour, Philo, and Basher series (U.S. Dept. of Agriculture, 1972), which are highly fertile and of silt-loam and sandy-loam textures. These soils are classified as deep and moderately well drained.

The climate is continental-temperate, and the average annual temperature is 10.5°C. The highest annual temperature usually occurs in July or August, and the lowest in December through February. The average annual precipitation is 965 mm; the greatest amount of monthly precipitation usually occurs in July (U.S. Dept. of Commerce, 1971). The average annual evaporation from the lake surface, as estimated from a U.S. Weather Bureau publication by Kohler and others (1959), is 737 mm. Prevailing winds are from the west in fall, winter, and spring and from the southwest during summer.

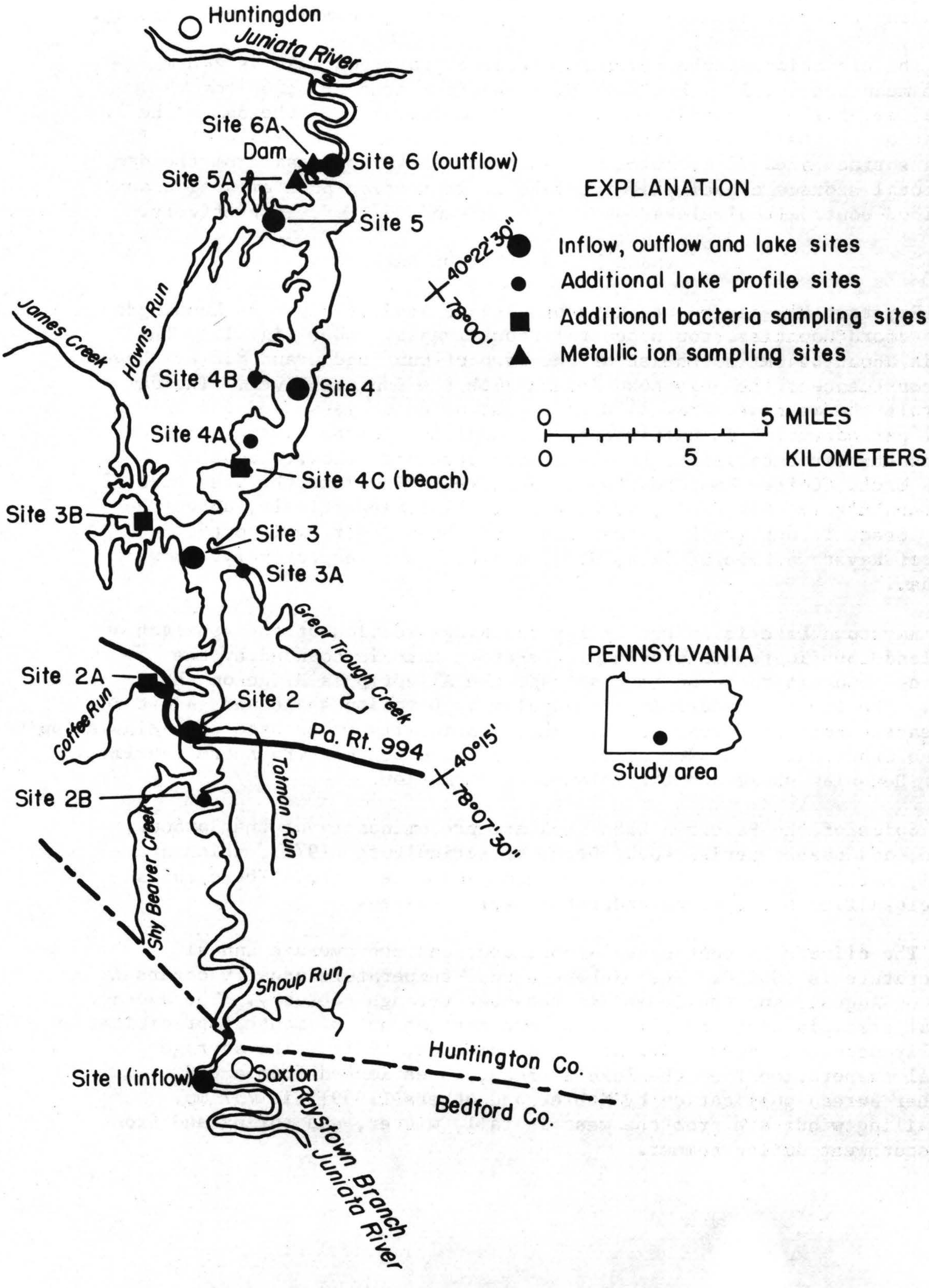

Figure 1.--Data-collection sites in the Raystown Lake study area.

Table 1.--Data-collection sites

Station No.	USGS Reference No.	Distance above the dam (km)	Station Name
1	01562000	62.3	Raystown Branch Juniata River at Saxton, Pa.
2	401842078105301	39.9	Raystown Lake near Entriken, Pa.
3	402117078082501	29.8	Raystown Lake near Marklesburg, Pa.
4	402246078034201	17.9	Raystown Lake near Hesston, Pa.
5	402535078014701	5.6	Raystown Lake near Huntingdon, Pa.
6	01563200	1/ 1.6	Raystown Branch Juniata River near Huntingdon, Pa.
2A	-	39.1	Raystown Lake at Coffee Run inlet.
2B	-	43.3	Raystown Lake just above Shy Beaver Creek inlet.
3A	-	29.0	Raystown Lake at Trough Creek inlet.
3B	-	28.3	Raystown Lake at James Creek inlet.
4A	-	18.7	Raystown Lake near Seven Points Recreation Area.
4B	-	16.6	Raystown Lake at small cove.
4C	-	19.6	Raystown Lake near swimming beach area.
5A	-	0.2	Raystown Lake near tunnel intake.
6A	-	0.0	Raystown Branch Juniata River at tunnel outlet.

1/ Kilometers below the dam.

DATA-COLLECTION SITES

Table 1 and figure 1 give the name and locations of all data-collection sites. The main inflow site (site 1) was at the USGS gaging station on Pennsylvania Route 913 at Saxton, Pennsylvania, about 3.2 km upstream from the lake. The outflow site (site 6) was at the USGS gaging station 1.6 km downstream from the dam. Prior to October 1, 1969, this gaging station was at Hawns bridge, 7.2 km upstream from its present location.

The four principal lake-sampling sites (5, 4, 3, 2) were 5.6, 17.9, 29.8, and 39.9 km, respectively, above the dam.

During the last 6 months of sampling, fecal coliform and fecal streptococcus bacteria counts were made at three additional lake sites; the Seven Points swimming beach area (site 4C), Coffee Run inlet (site 2A), and James Creek inlet (site 3B). In the last two months of sampling, lake-profile data were collected at five additional sites (2A, 2B, 3A, 4A, 4B). Samples for metallic-ion analyses were collected from water near the lake bottom just above the dam (site 5A) and from the tunnel outflow (site 6A).

SAMPLING FREQUENCY AND METHODS

Sampling at the inflow, outflow, and the four main lake sites was generally conducted bimonthly from May 1974 to March 1976 (except in January 1976) and monthly from May through September 1976.

On July 20 and 21, 1976, a diel study of bihourly fluctuations in temperature, dissolved-oxygen concentration, pH, and specific conductance in the vertical profile was made at site 4. Sampling began at 1800 hours on July 20 and ended at 1600 hours on July 21.

Periodic temperature measurements were made using a calibrated, handheld thermometer. Specific conductance and pH were measured using standard meters. Alkalinity was determined immediately after sample collection by titration with 0.01639 N sulfuric acid to a pH of 4.5. Dissolved-oxygen concentration was determined by the Winkler method, as described by Brown and others (1970). Vertical lake-profile measurements were taken with a Yellow Springs Instrument[2/] temperature-dissolved-oxygen meter between May 1974 and May 1975, and with a NERA Environmental Monitor between July 1975 and September 1976. Because of lake instability during the filling process, only profile data collected after February 1975 are used in the discussion.

2/ The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Laboratory chemical analyses of water were made using the techniques described in Brown and others, (1970). The AGP was determined using methods described by Shoaf and Lium (1975). Plankton samples were collected with a messenger-tripped lucite water-sampling bottle. Each plankton sample, collected at a depth of 2 m, consisted of 3 L of water that was filtered through a Wisconsin-type plankton net and preserved with a standard merthiolate (Weber, 1973) solution. Concentrations of sanitary bacteria were determined by the membrane filtration method, as described by Slack and others (1973). Light penetration in the lake was measured with a Secchi disc having a diameter of 203 mm (Welch, 1948, p.159).

PHYSICAL AND CHEMICAL DATA

Depth-Profile-Measurements

Temperature

Temperature is important to the chemical reactions and biological processes that occur in lake waters. From the temperature data collected, Raystown Lake can be classified as a dimictic lake, or one having two overturns each year, one in spring and one in autumn. Thermal stratification was direct in summer, but profile measurements taken in January 1975 indicate that inverse thermal stratification will occur, particularly when the lake surface is frozen.

In March 1975 and again in March 1976, water temperatures from the surface to the bottom of the lake were nearly homothermous. In May 1975 the temperature gradually dropped from 24.5°C to 6.5°C from the surface to a depth of 15 m. From 15 m to the lake bottom, the temperature remained near 6.5°C. In May 1976 from the surface to a depth of 15 m, the temperature decreased from 15.0°C to 7.0°C, and from 15 m to the bottom the temperature dropped 2.0°C. Temperature profiles taken in May of 1975 and 1976 indicated that thermal stratification had begun. In July 1975 and again in July 1976, thermal stratification was well developed throughout the lake. In July 1975 temperatures from the surface to a depth of about 5 m (the epilimnion) varied by only 2.0° or 3.0°C. From a depth of 5 m to about 9 m (the metalimnion), temperature declined 12°C. From a depth of 9 m to the bottom (the hypolimnion), the temperature decline was again gradual. Thermal stratification was well established again in July 1976, but the depth and thickness of the metalimnion was different. Summer thermal stratification probably will be an annual event in Raystown Lake, but because of climatological factors, such as wind action, light absorption, air temperature, and variations in the level of release from the dam, the timing and degree of stratification will vary from year to year.

In November 1975 the surface temperature was 6.0°C higher than the bottom temperature and the thermal gradient was much lower than in July 1975, which indicates that the autumn overturn was in progress. Autumn overturn is initiated by a cooling of lake waters towards uniform density. Because of the depth and the low surface to volume ratio of Raystown Lake, autumn overturn will take longer than for other, more shallow lakes in the state.

Figure 2 shows temperature and dissolved oxygen profiles at lake site 5. The temperature profile for July 1975 shows summer thermal stratification; the temperature profile for November 1975 shows the lake progressing towards autumnal overturn; and the temperature profile for March 1976 shows the lake in a homothermous condition.

Dissolved Oxygen

Dissolved oxygen is considered one of the most significant chemical substances in natural waters. It acts as a regulator of metabolic processes of organisms; because of this physiological function, its concentration is a good indicator of lake conditions.

The two primary sources for dissolved oxygen in water are the atmosphere and photosynthetic activity. Oxygen from photosynthetic activity is limited to the depth that light penetrates sufficiently to permit photosynthesis. This upper region of a lake is known as the euphotic zone. Because of the low productivity per unit volume, there was little oxidation in the hypolimnion, and the dissolved-oxygen concentration remained relatively high throughout the vertical profile at lake sites 4 and 5. In all profiles for lake sites 4 and 5, the dissolved-oxygen concentration within 1.0 m of the lake bottom was never less than 2 mg/L, and usually was greater than 5 mg/L. In September 1975, and again in July, August, and September, 1976, there was a marked drop in the hypolimnic, dissolved-oxygen concentration at site 2, the lake site nearest the inflow. There was also a dissolved-oxygen drop in the hypolimnion at site 3. Nutrients from the inflow enabled greater plankton growth at these two sites, thereby limiting light penetration in the hypolimnion. The oxidation and respiration processes in the hypolimnion consumed the available oxygen faster than it was produced by photosynthesis, thus creating the low oxygen content. Figure 3 illustrates the hypolimnic oxygen deficiencies measured at site 2.

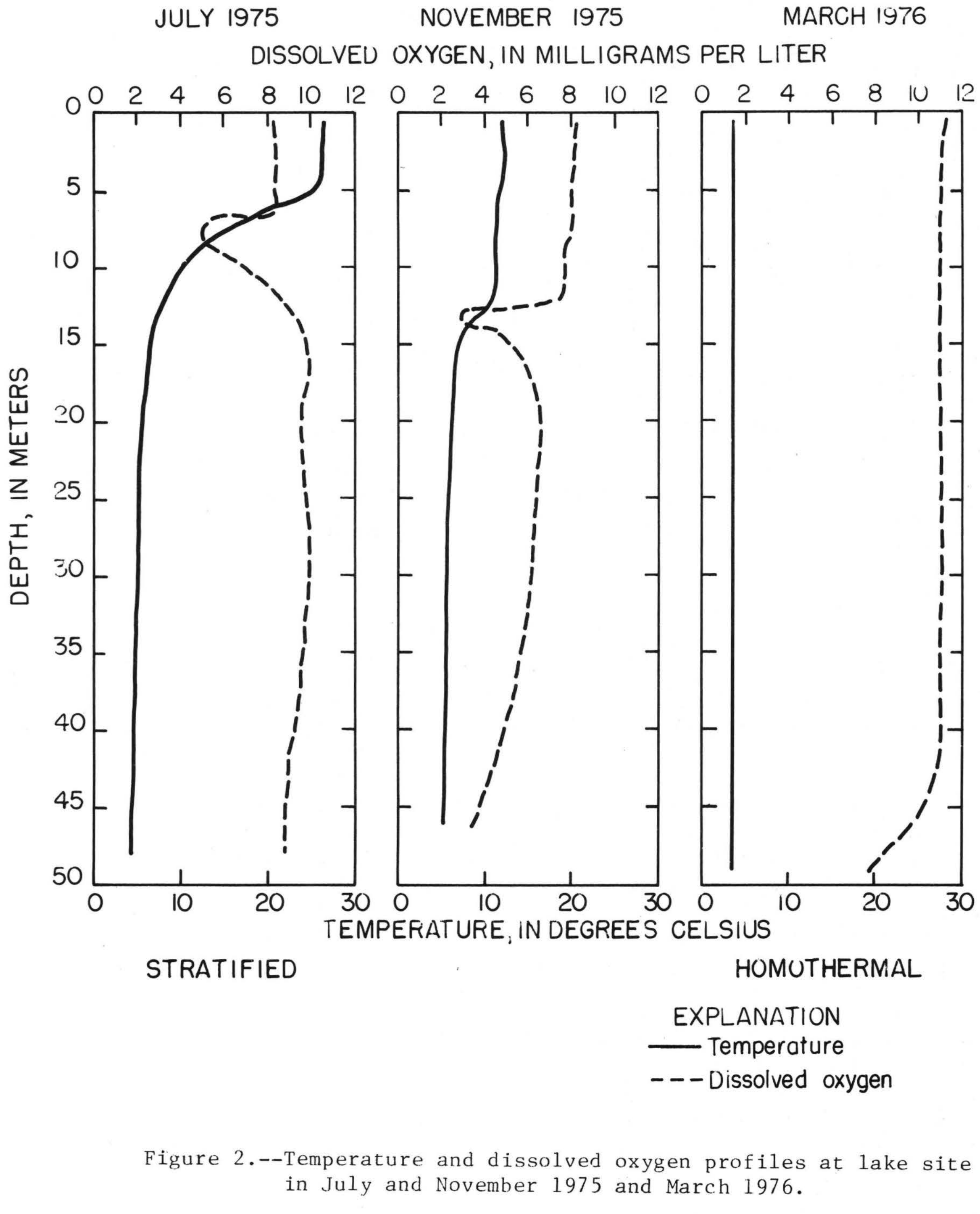

Figure 2.--Temperature and dissolved oxygen profiles at lake site 5 in July and November 1975 and March 1976.

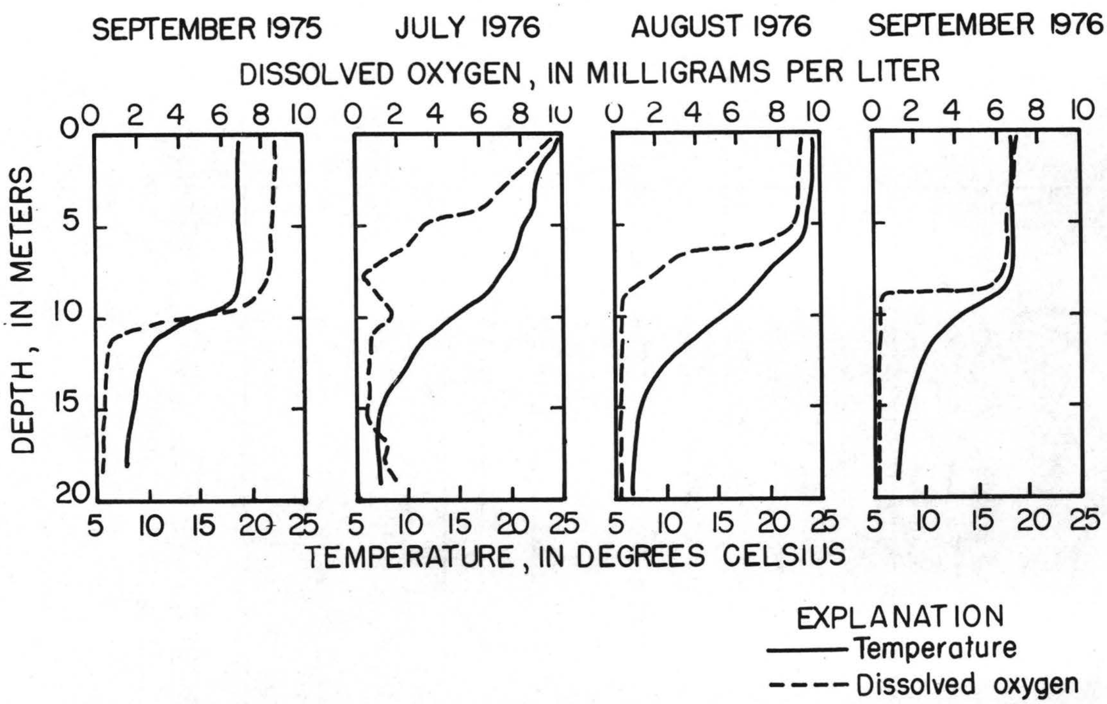

Figure 3.--Temperature and dissolved-oxygen profiles at lake site 2 in September 1975 and July, August, September, 1976.

A sharp decline in the oxygen concentration in the metalimnion and then an increase in the oxygen throughout the hypolimnion was observed from the depth-profile data. This condition occurred in July, September, and November, 1975 and again in August and September of 1976; it was most apparent at the two deepest lake sites, 4 and 5, although it did occur to some extent at sites 2 and 3. Figure 2 illustrates the metalimnic oxygen minimum observed at site 5 in July and November 1975. The settling velocity of dead plankton and other organic matter through the epilimnion was reduced by the colder, more dense water in the hypolimnion. Because their descent was slowed, a zone of accumulation resulted, and the plankton and other organic material were decomposed by bacteria and removed oxygen from the metalimnion. Hutchinson (1957, p. 621) refers to this type of an oxygen curve as a negative heterograde curve.

pH

The reaction of dissolved carbon dioxide in water, represented by the three equations below, is one of the most important reactions affecting pH; this reaction forms the basis for the discussion of pH in Raystown Lake.

$$CO_2\ (aq) + H_2O \rightarrow H_2CO_3\ (aq) \qquad (1)$$

$$H_2CO_3\ (aq) \rightarrow H^+ + HCO_3^- \qquad (2)$$

$$HCO_3^- \rightarrow H^+ + CO_3^{-2} \qquad (3)$$

The pH is inversely proportional to the hydrogen ion (H^+) concentration.

In practically every place where water is neither very acid or very alkaline, as in Raystown Lake, it may be assumed that the pH is regulated by this carbon dioxide (CO_2) - bicarbonate (HOC_3^-) - carbonate (CO_3^{-2}) system. (Hutchinson, 1957, p. 682.)

The pH range in Raystown Lake was 6.5 to 8.5. The higher pH values (>8.0), which were generally measured in the upper 5 m of the lake, were attributed to photosynthetic activity. The photosynthetic process requires carbon dioxide. A decrease in carbon dioxide produces a decrease in the hydrogen ion concentration and an increase in pH. (See equations 1, 2, and 3.) The vertical distribution of pH in Raystown Lake is determined by the utilization of carbon dioxide in the trophogenic zone and the liberation of carbon dioxide in the tropholytic zone. From the lake surface to the bottom of the trophogenic zone, light penetration and photosynthesis gradually decreases, causing a slight decrease in pH. In the tropholytic zone, decomposition and respiration produces carbon dioxide, maintaining the lower pH.

During summer stagnation periods, the vertical distribution of carbon dioxide and bicarbonate is often roughly the inverse of the oxygen distribution (Hutchinson, 1957, p. 689). This explains the sudden drop in pH associated with the metalimnic oxygen minimums observed in July, September, and November 1975 and August and September 1976.

Specific Conductance

The average specific conductance of the surface waters of Raystown Lake (fig. 4) decreased toward the outflow. As the water passes through the lake, the phytoplankton and zooplankton extract nutrients and other inorganic substances, which decreases the total ion concentration, and consequently decreases specific conductance. Chemical precipitation is also a factor that may contribute to the decrease in specific conductance from inflow to outflow. An increase in specific conductance from the lake surface to the bottom, as normally occurs in deep stratified lakes, was not observed. A gradual decrease was observed from the lake surface to the bottom. A possible explanation for this occurrence is that most of the hypolimnetic waters in Raystown Lake are the cold inflows of winter and spring. These inflows are usually higher in volume and have lower specific conductance. The warmer low-volume, high specific-conductance inflows of summer and fall will tend to spread across the surface of the lake, thus setting up the inverted specific-conductance profile.

Depth-profile measurements taken at five additional lake sites in August and September 1976, indicated that profile characteristics at these sites were similar to the profile characteristics of the main body of the lake.

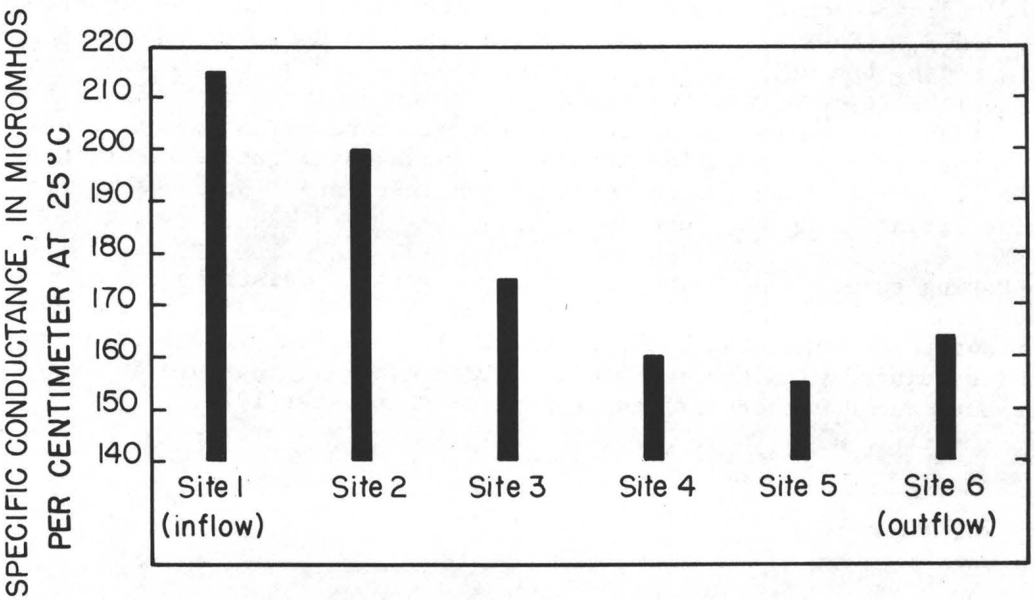

Figure 4.--Range of specific conductance of the inflow, outflow, and lake surface.

Diel Measurements

On July 20 and 21, 1976, diel fluctuations of temperature, dissolved oxygen, pH, and specific conductance were measured at lake site 4. Profile measurements were taken every 2 hours, starting at 1800 hours on July 20 and ending at 1600 hours on July 21. Weather conditions at the start of the diel study were normal for the month of July, and clear skies, warm temperatures, and a southwesterly wind of 10 mph prevailed. Throughout the night, the winds were calm and the air temperature mild. At dawn on July 21, and until 1400 hours, the winds were calm, temperatures mild, and the sky was hazy and overcast. At 1400 hours on July 21, a light drizzle started to fall.

Diel fluctuations were scant areally and with depth throughout the 24-hour period. Lake-surface temperatures varied by only 1.0°C, from a maximum of 24.5°C to a minimum of 23.5°C. At depths greater than 1 m, the temperature remained relatively constant throughout the 24-hour period. The dissolved oxygen concentration of the surface water varied by only 0.2 mg/L from 9.3 mg/L at 2000 hours on July 20 to 9.1 mg/L at 0600 hours on July 21.

The pH of the surface waters varied by only 0.1, from a pH of 8.4 during most of the daylight hours to a pH of 8.3 during the night.

Specific conductance varied only slightly during the 24-hour period. A maximum surface conductance of 171 micromhos per centimeter at 25°C was measured at 2400 hours on July 20 and a minimum surface conductance of 155 µmho/cm was measured at 2000 hours on July 20.

Of the four parameters measured during the diel study, temperature is the only one that is independent of biological conditions in the lake. Fluctuations in dissolved oxygen content, pH, and specific conductance are related either directly or indirectly to the trophic state of the lake. If Raystown Lake was in an eutrophic rather than an oligotrophic state, diel fluctuations of dissolved oxygen concentrations, pH, and specific conductance would have been more pronounced.

Alkalinity

Alkalinity is a measure of the buffering capacity or the ability of water to neutralize acids. The alkalinity of the surface water at each lake site and at the inflow and outflow was measured on each sampling visit. Figure 5 shows the range and mean concentrations measured at each site. The alkalinity gradually decreased from the inflow to the outflow; this decrease was much less apparent from lake site 3 to the outflow. The oxidation of ammonia nitrogen to nitrite and nitrate causes a destruction of alkalinity (Symons, 1969), which is a partial explanation for the decrease in alkalinity from inflow to outflow.

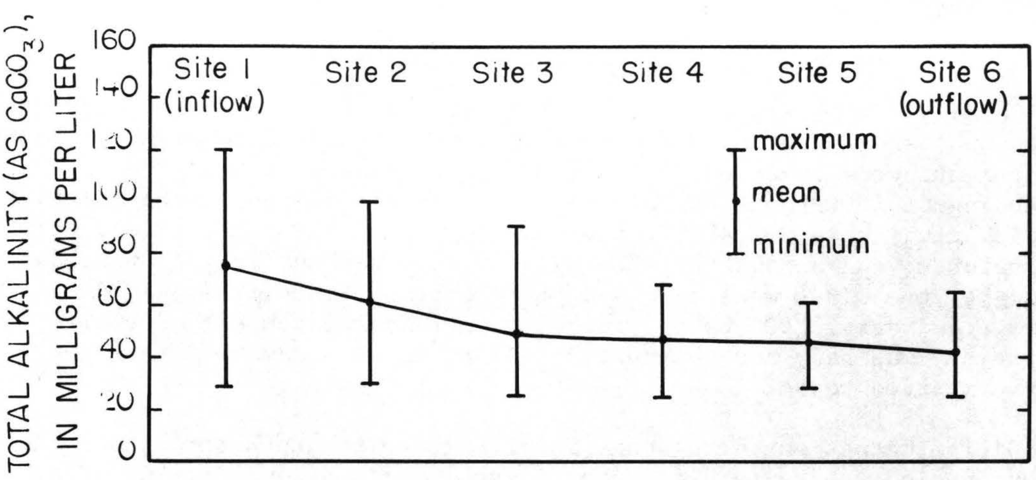

Figure 5.--Maximum, minimum, and mean concentrations of alkalinity measured at the inflow, outflow, and lake surface.

Lake Nutrients

Aquatic vegetation need at least 15 nutrients, 2 of which are nitrogen and phosphorus, for growth. Nitrogen and phosphorus usually occur in low concentrations in most natural waters, and phosphorus may be completely removed from solution by phytoplankton during high production periods. When adequate supplies of these nutrients are available, high production of aquatic vegetation can occur. Chemical analyses of the surface and bottom waters of Raystown Lake were made to determine concentrations of nitrogen and phosphorus species in order to estimate the trophic state of the lake. A summary of nitrogen and phosphorus data collected in Raystown Lake is given in table 2.

Nitrogen

Nitrogen in water occurs in two reduced forms, organic nitrogen (nitrogen bound in cellular material) and the ammonium ion (NH_4+). The organic nitrogen content is a valuable indication of the productivity of a body of water because most of the organic nitrogen is ultimately transformed into forms that can enter into production of living matter. About 30 percent of the total nitrogen measured in Raystown Lake was in the form of organic nitrogen. Throughout the study period, observed lake-surface concentrations of organic nitrogen ranged from 0.11 to 0.70 mg/L, and bottom concentrations ranged from 0.13 to 0.56 mg/L. There was a decrease in the average organic nitrogen concentrations in the surface waters at sites 2, 3, 4, and 5 of 0.37, 0.34, 0.33, and 0.29 mg/L, respectively. The average bottom concentrations of organic nitrogen at sites 2, 3, 4, and 5, were 0.38, 0.35, 0.37, and 0.36 mg/L, respectively.

Nitrogen that is chemically bound in organic compounds is returned to the environment through decomposition by microorganisms; the end product of the first stage of oxidative degradation is ammonia. In unpolluted waters, ammonia and ammonium compounds occur in relatively small quantities, usually on the order of 1.0 mg/L or less (Reid, 1961, p. 185). Measured ammonium concentrations of the surface waters of Raystown Lake were all less than 0.17 mg/L, and 88 percent of surface samples collected had concentrations less than 0.10 mg/L. The lake bottom waters had higher concentrations of ammonium, which probably was due to bacterial decomposition of organic material. About 90 percent of the bottom samples had ammonium concentrations of less than 0.50 mg/L. As lake conditions became more stable in March 1975, smaller amounts of ammonium were present in both surface and bottom waters.

Table 2.--Summary of nitrogen and phosphorus data collected in Raystown Lake from May 1974 through July 1976. (Analyses in milligrams per liter)

Site No.			Organic Nitrogen	Ammonium Nitrogen (N)	Nitrate-Nitrogen (N)	Ortho-phosphate (P)	Total Phosphorus (P)
2	Surface	Maximum	0.55	0.16	1.40	0.04	0.07
		Minimum	.16	.00	.41	.00	.01
		Mean	.37	.06	.84	.01	.02
	Bottom	Maximum	.53	.77	1.40	.02	.07
		Minimum	.16	.01	.04	.00	.01
		Mean	.38	.17	.83	.01	.04
3	Surface	Maximum	.56	.09	1.50	.02	.04
		Minimum	.17	.00	.34	.00	.01
		Mean	.34	.05	.78	.01	.02
	Bottom	Maximum	.55	.82	1.40	.02	.04
		Minimum	.15	.00	.04	.00	.01
		Mean	.35	.26	.83	.01	.02
4	Surface	Maximum	.70	.17	1.30	.01	.03
		Minimum	.17	.00	.32	.00	.00
		Mean	.33	.05	.76	.00	.01
	Bottom	Maximum	.54	.22	1.30	.01	.04
		Minimum	.26	.01	.54	.00	.01
		Mean	.37	.08	.94	.00	.02
5	Surface	Maximum	.47	.13	1.20	.00	.02
		Minimum	.11	.00	.34	.01	.00
		Mean	.29	.05	.75	.00	.01
	Bottom	Maximum	.56	.19	1.40	.02	.03
		Minimum	.13	.00	.68	.00	.01
		Mean	.36	.08	1.01	.00	.01

Nitrogen occurs in water in two oxidized forms, as nitrite (NO_2^{-2}) and nitrate (NO_3^-). Nitrite-nitrogen (NO_2^{-2}-N) occurs in very minute quantities, if at all, in unpolluted waters. Nitrate-nitrogen (NO_3^--N) is the form most easily taken up by most aquatic vegetation for protein synthesis. Concentrations of NO_3^--N in the surface water, for all lake sites, ranged from 0.32 to 1.5 mg/L, and bottom concentrations ranged from 0.04 to 1.4 mg/L. The average surface concentrations of NO_3^--N measured at sites 2,3,4, and 5, were 0.84, 0.78, 0.76, and 0.75 mg/L, respectively. The average bottom concentrations of NO_3^--N measured at sites 2, 3, 4, and 5 were 0.83, 0.83, 0.94 and 1.0 mg/L, respectively.

Figure 6 shows the seasonal fluctuations in the average NO_3^--N concentrations measured at the surface and bottom throughout the study period. The decline of the surface NO_3^--N concentrations after the early spring maximums in 1974, 1975, and 1976 is the result of NO_3^--N assimilation by the phytoplankton.

Phosphorus

The mean total phosphorus content of most lakes ranges from 0.01 to 0.03 mg/L (Reid, 1961, p. 188). Total phosphorus concentrations of the surface waters of Raystown Lake ranged from 0.00 to 0.07 mg/L. The mean surface concentration of total phosphorus throughout the study period at sites 2 and 3 was 0.02 mg/L and the mean concentration at sites 4 and 5 was 0.01 mg/L. Bottom concentrations of total phosphorus at all sites were slightly higher, averaging 0.01 mg/L more than surface concentrations.

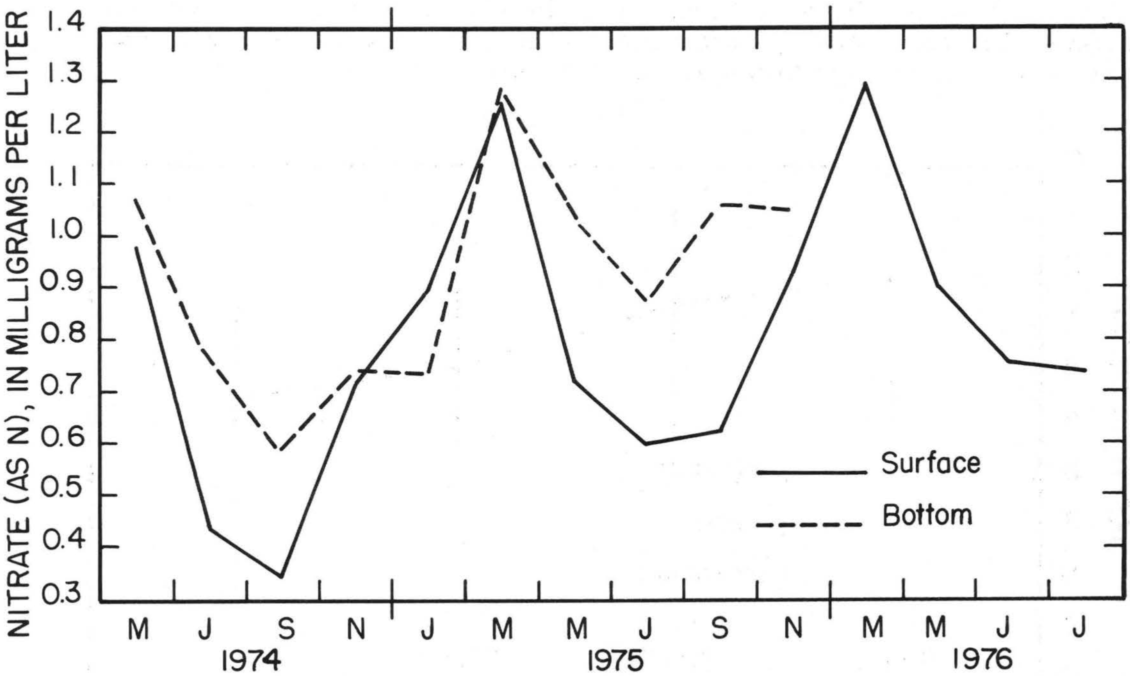

Figure 6.--Seasonal fluctuations in the average nitrate-nitrogen concentrations measured at the surface and bottom throughout Raystown Lake.

Orthophosphate (PO_4^{-3}) is the inorganic form of phosphorus most used by aquatic vegetation in metabolic processes. At each lake site, the surface and bottom concentrations of PO_4^{-3} were nearly the same. In a few samples, higher concentrations of PO_4^{-3} occurred in the bottom water. There was evidence of a gradual decrease in the surface PO_4^{-3} concentration from site 2 to site 5. The average surface concentrations at sites 2, 3, 4, and 5 were 0.01, 0.01, 0.00, and 0.00 mg/L, respectively. Apparently the PO_4^{-3} ion was depleted by the phytoplankton and sediment as water passed through the lake.

Secchi Disc Transparency

Because the quantity of light and depth to which it penetrates are significant factors in determining the amount and form of biological productivity, measurements of the water's transparency were made by lowering a Secchi disc until it was no longer visible, usually when less than 5 percent of the sunlight is transmitted (Reid, 1961, p. 100). Secchi disc transparencies measured in Raystown Lake ranged from a minimum of 0.10 m at site 2 near the head of the lake to a maximum of 9.0 m at site 5 near the dam. Table 3 is a compilation of Secchi disc transparencies taken during the study period. At site 2, not only are many of the finer sediment particles carried by the inflow still in suspension, but the total nutrient supply is greatest at this site and caused a more abundant phytoplankton population than at any other site. As water passes through the lake, most of the fine, suspended-sediment particles settle out, the nutrient supply becomes less, phytoplankton growth is reduced and, consequently, transparency increases. Figure 7 illustrates the gradual increase in the average transparency from site 2 to site 5.

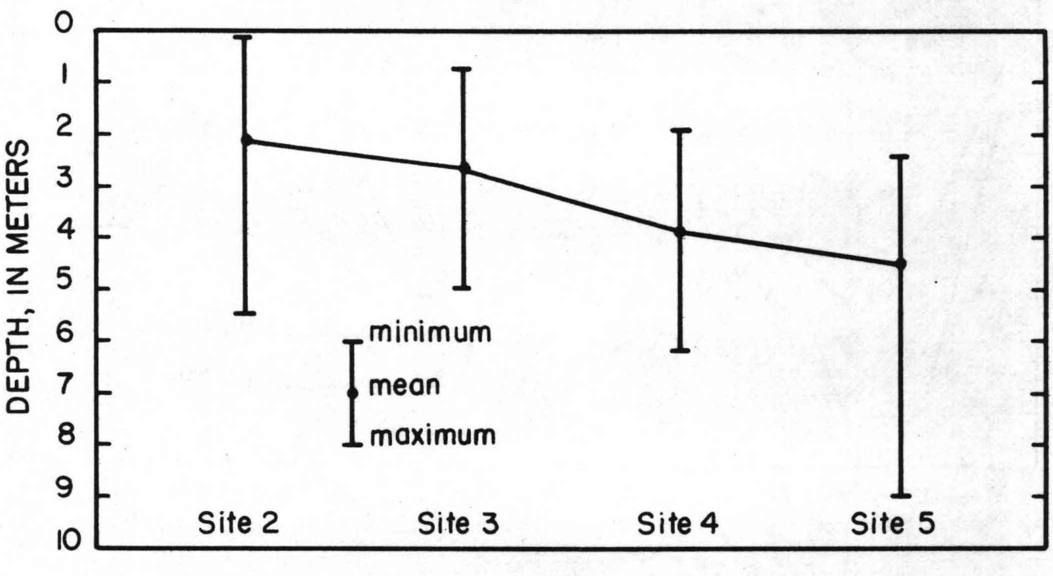

Figure 7.--Maximum, minimum, and mean Secchi disc transparencies at the four main lake sites.

Table 3.--Secchi disc transparencies throughout Raystown Lake. (Depth in meters.)

Date	Site Number								
	2	3	4	5	2A	2B	3A	4A	4B
5-14-74	0.46	1.90	3.0	2.90					
7-16-74	1.12	1.88	4.6	5.8					
9-19-74	3.6	4.0	6.1	9.0					
11-20-74	2.69	2.44	3.9	4.0					
1-08-75	.84	1.52	4.7	5.9					
3-20-75	.10	1.07	1.98	2.44					
5-21-75	1.07	2.13	2.90	2.92					
7-23-75	4.1	4.6	5.8	5.3					
9-24-75	1.52	2.21	2.13	2.44					
11-19-75	1.85								
11-20-75		2.74	2.29	3.0					
3-02-76									
3-03-76	1.07	.76	1.90	2.67					
5-11-76				6.1					
5-12-76	2.59	3.4	5.2						
6-15-76			6.2	5.2					
6-16-76	5.5	5.0							
7-20-76	2.44	2.59							
7-21-76			4.1	5.0					
8-17-76			3.5	5.5				3.4	4.4
8-18-76	2.44	2.90			2.90	2.44	2.59		
9-28-76			3.5	4.0				2.59	2.97
9-29-76	2.44	3.0			1.98	2.13			

Metallic Ions

Metallic ions present in a lake ecosystem can greatly affect the potential utility of the water and can control or alter the entire aquatic environment. Many metallic ions are necessary in trace concentrations for normal plant and animal metabolism; however, when trace concentrations are exceeded, toxic conditions for both plants and animals may result.

Metallic-ion concentrations determined for bottom waters near the breast of Raystown Dam (site 5A) and at the tunnel outflow (site 6A) indicated no toxic levels were present for fish and other aquatic life (McKee and Wolf, 1971). Results of the analyses are summarized in table 4.

Table 4.--Dissolved Metallic-ion concentrations measured in the lake bottom water near Raystown Dam and at the tunnel outflow on March 2, 1976. (Symbol <, less than)

Location and site	Aluminum	Arsenic	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Selenium	Silver	Zinc
	(micrograms per liter)												
Raystown Lake near dam; 5A	30	0	1	<10	0	30	10	7	20	<0.5	0	0	110
Tunnel outflow; 6A	40	0	1	<10	0	0	10	3	20	<0.5	0	0	10

BIOLOGICAL DATA

Algal Growth potential

Algal growth potential (AGP) is a biological test to determine the maximum algal mass (dry weight) of a test algal species (*Selenastrum capricornatum*) that can be grown in a natural water sample under standardized laboratory conditions. The AGP data that are derived in the laboratory under controlled conditions of light and temperature do not necessarily reflect conditions in the natural aquatic environment from which the samples are taken as only the growth potential at a given time is measured, and many environmental factors that could alter the AGP cannot be simulated in a laboratory.

Algal growth potential was determined for the surface water at the four main lake sites in March 1976 and May through September 1976. The data summarized in table 5 indicates that the AGP was similar for all four sites in May, June, and July. The lowest AGP, 0.0 mg/L, occurred in May, and the highest AGP, 1.8 mg/L, occurred in June. According to a classification made in a study conducted by the Environmental Protection Agency (Miller and others, 1974, p. 671) on 49 lakes throughout the United States, Raystown Lake can be classified as a moderately productive lake on basis of the average AGP of 0.3 mg/L for the July sampling.

Algal assays were conducted on lake samples collected in May, August, and September to determine which nutrients, if any, could be considered growth-limiting. The two nutrients added to the samples were nitrate (NO_3^-) and orthophosphate (PO_4^{-3}). The practice of adding such nutrients to a water sample is called "spiking". Base-level concentrations of NO_3^- and PO_4^{-3} were determined for the control samples and 10 times the base-level amount of each nutrient was added to 100-mL aliquots of the raw, filtered water. The spiked samples were incubated under standardized conditions. Table 6 summarizes the spiking results and indicates that PO_4^{-3} was a growth-limiting nutrient in most of the water tested, but very little change was observed in the algal growth of samples spiked with NO_3^-. More than a 20-fold increase in algal growth was observed in all but one of the samples spiked with PO_4^{-3}. The one exception to the growth increase of the PO_4^{-3} spiked samples was observed for the sample collected in May at site 4. A zero growth potential was observed for all 100-mL-aliquot samples. Insufficient data was collected to explain this occurrence.

In five of the samples assayed, the increased growth from the addition of PO_4^{-3} was even greater with the addition of both PO_4^{-3} and NO_3^-. This indicates that although PO_4^{-3} was initially growth-limiting for algae, NO_3^- became growth-limiting when adequate PO_4^{-3} was present.

Table 5.--Summary of algal-growth-potential data collected at the four main lake sites in 1976

[Analyses in milligrams (dry weight) per liter]

Site No.	March	May	June	July	August	September
2	0.5	0.0	1.7	0.3	0.6	0.2
3	2.2	0.0	1.8	0.3	0.3	0.5
4	1.6	0.0	1.9	0.3	0.3	0.5
5	0.4	0.0	1.8	0.3	0.3	0.4

Table 6.--Summary of algal growth potential of untreated lake samples (controls) and samples with 10 times the base amount of nitrate (NO_3^-), orthophosphate (PO_4^{-3}), or both.

[Analyses in milligrams (dry weight) per liter]

Site Number	Control	Spiked Samples NO_3^-	PO_4^{-3}	$NO_3^- + PO_4^{-3}$
		May 1976		
2	0.0	0.0	29.0	24.1
3	0.0	0.0	16.0	29.0
4	0.0	0.0	0.0	0.0
5	0.0	0.0	24.0	33.9
		August 1976		
2	0.6	0.6	16.6	16.5
3	0.3	0.4	11.0	8.8
4	0.3	0.3	11.0	15.5
5	0.3	0.3	13.8	15.6
		September 1976		
2	0.2	0.3	14.6	17.3
3	0.5	0.4	19.0	16.4
4	0.5	0.4	13.6	13.0
5	0.4	0.3	13.0	13.0

Chlorophyll *a*

Chlorophyll is found in all green plants and is the molecule that absorbs light energy from the sun and transforms it into chemical energy in the photosynthetic process. Chlorophyll production and content in any aquatic environment is dependent upon light, nutrients, temperature, and other factors; but at constant light intensity, a constant relation appears to exist between photosynthesis and chlorophyll *a* (Reid, 1961, p 329). This relationship served as a useful measure of the production rate throughout Raystown Lake, because light conditions and cloud cover at all four lake sites were similar for all samplings. For several samplings a progressive decline in chlorophyll *a* concentration was observed between sites 2 and 5, which indicates a decline in productivity from inflow to outflow. This was anticipated because nutrients entering the lake from the main inflow were gradually depleted, as indicated, by the earliest nutrient samples. Results of the chlorophyll *a* analyses of the surface waters of Raystown Lake for May 1974 to July 1976, are given in table 7.

Plankton

Data in tables 8 and 9 indicate that the diatoms (Chrysophyta) were the most commonly found group of phytoplankton during the study period. In all samples during September 1975 to July 1976, Asterionella and Dinobryon were the co-dominant genera. The dinoflagellate Ceratium was also present in most samples. Green algae (Chlorophyta) and blue-green algae (Cyantophyta) were observed mostly during the summer.

The phytoplankton count rarely exceeded 100 cells/mL. The cell count for November 1975 averaged 41 cells/mL, and that for May, June, and July 1976 averaged less that 5 cells/mL.

The composition of phytoplankton communities can often be correlated with trophic stages of lakes (Reid, 1961, p. 298). Oligotrophic lakes are characterized by a relatively low quantity of phytoplankton and pulses, or fluctuations in abundance, are uncommon. Eutrophic lakes generally support a large quantity of phytoplankton, and pulses are frequent. From the limited amount of phytoplankton data collected, Raystown Lake could be characterized as oligotrophic.

Few zooplankton were present throughout the study period. The zooplankton identified in the samples were composed predominantly of rotifers and microcrustaceans. Microcrustaceans identified were Daphnia (Order Cladocera) and Cyclops (Order Copepoda). The Cladocera and Copepoda live in most fresh-water systems. Rotifers identified in the lake samples belonged to the genera Kerotella, Kellicottia, Polyarthra, and Trichocerca.

Plankton sampling during the study period was insufficient for a thorough understanding of the distribution, diversity, and densities of plankton populations in Raystown Lake.

Table 7.--Summary of chlorophyll *a* concentrations in the surface water at the four main lake sites.

[Analyses in micrograms per liter. Symbol <, less than]

Date	Site 2	Site 3	Site 4	Site 5
5-14-74	<1.0	<1.0	<1.0	<1.0
7-16-74	5.5	3.8	1.0	<1.0
9-19-74	-	8.3	5.0	1.4
11-20-74	3.3	2.3	0.9	0.6
1-08-75	0.4	0.3	0.3	0.2
3-20-75	2.9	0.4	0.6	1.1
5-21-75	-	2.9	1.4	1.1
7-23-75	0.8	0.6	0.6	0.7
9-24-75	8.3	5.9	3.1	2.5
11-19-75	2.0	1.3	5.2	2.4
3-03-76	1.2	0.4	0.6	0.4
5-12-76	2.3	0.0	0.0	0.0
6-16-76	0.0	0.0	0.0	0.0
7-20-76	4.9	7.2	6.1	2.0

Table 8.--Qualitative identification and distribution of plankton in samples collected between July 1974 and July 1975.

Organism		July 1974	September 1974	November 1974	January 1975	March 1975	July 1975
Phytoplankton							
Chrysophyta	*Asterinella* sp.	5	2,3,5	2,4,5	2,3,4,5	2,3,4,5	2,3,4
(yellow-green algae)	*Dinobryon* sp.		3,4,5	4			
	Fragilaria sp.	3,4,5	2,3,4,5	2,3,4,5	2,3,4,5		2,3,4
	Melosira sp.			2,3			
	Navicula sp.		2				
	Tabellaria sp.	5	3	2,4,5	2,4,5	2,3,4,5	
Chlorophyta	*Microspora* sp.	2	2,3,4		2,3,5		
(green-algae)	*Pediastrum* sp.	2,3,4	2,3,4,5				
	Spirogyra sp.	2					
	Staurastrum sp.	2	2		2,4,5		
	Palmella sp.						3,5
Pyrrhophyta (dinoflagellates)	*Ceratium* sp.	2,3,5	2,3,4,5		4,5		2,3,4,5
Cyanophyta	*Anabaena* sp.	4	2,3,4				2
(blue-green algae)	*Anacystis* sp.		4				3,4,5
	Phormidium sp.		3		2		
Zooplankton							
Arthropoda							
Cladocera		2,3,4,5	2,3,4		4,5	2	
Copepoda		5				2	
Rotifera		2,3,4,5	2,3,4		3,4,5	2	

The numbers below the dates refer to the lake site at which the indicated organism was sampled.

Table 9.--Qualitative and quantitative identification of phytoplankton in samples collected between November 1975 and July 1976.

Site No.	September 1975 Genera	%	November 1975 Genera	%	May 1976 Genera	%	June 1976 Genera	%	July 1976 Genera	%
	Dinobryon	79	*Asterionella*	34	*Asterionella*	100			*Asterionella*	59
	Asterionella	13	*Ceratium*	9					*Dinobryon*	17
2			*Pediastrum*	2					*Anaebana*	1
	Total cell count 128 cells/mL		Total cell count 1.6 cells/mL		Total cell count <1 cell/mL				Total cell count 1 cell/mL	
	Dinobryon	94	*Dinobryon*	57	*Asterionella*	97			*Dinobryon*	88
	Asterionella	4	*Asterionella*	26	*Fragilaria*	1			*Asterionella*	6
3			*Fragilaria*	4	*Ceratium*	1			*Ceratium*	6
	Total cell count 137 cells/mL		Total cell count 5.4 cells/mL		Total cell count 6 cells/mL				Total cell count 7 cells/mL	
	Dinobryon	93	*Dinobryon*	54			*Dinobryon*	75	*Dinobryon*	94
	Ceratium	4	*Asterionella*	29			*Asterionella*	13	*Ceratium*	4
4			*Fragilaria*	8			*Fragilaria*	9	*Asterionella*	1
	Total cell count 103 cells/mL		Total cell count 76 cells/mL				Total cell count 1 cell/mL		Total cell count <1 cell/mL	
	Dinobryon	94	*Dinobryon*	70			*Dinobryon*	46	*Dinobryon*	72
	Ceratium	2	*Asterionella*	21			*Asterionella*	17	*Ceratium*	24
5			*Fragilaria*	6						
	Total cell count 51 cells/mL		Total cell count 82 cells/mL				Total cell count <1 cell/mL		Total cell count 4 cells/mL	

Sanitary Bacteria

Raystown Lake provides ideal opportunities for water-based recreation, such as swimming and water skiing, and therefore it is important that the water be of suitable sanitary quality for water-contact recreation. Counts of fecal coliform (FC) and fecal streptococcus (FS) bacteria were made during the study period to determine bacteria densities at the inflow, the outflow, and at selected locations within the lake. Tables 10 and 11 summarize FC and FS densities measured during the study period. Most samples collected at the seven lake sites had very low densities of both FC and FS bacteria. All of the FC densities during the bathing season were within the limits established by the Pennsylvania Department of Environmental Resources for bathing beach areas (PA. Dept. of Environmental Resources, 1971). Water is considered contaminated when the FC density of any sample collected exceeds 1000 colonies per 100 mL. The highest FC density observed for the main inflow (site 1) was 590 per 100 mL and the median density observed at this site for the study period was 68 per 100 mL. Most of the FC densities in the outflow (site 6) were very low. A few samples collected at the outflow had higher FS densities than was expected. This was attributed to the waterfowl population that frequents the outflow area.

EFFECTS OF THE IMPOUNDMENT ON DOWNSTREAM WATER QUALITY

The effects of the impoundment on downstream water quality can be estimated from figure 8 by comparison of the physical, chemical, and bacteriological characteristics of inflow and outflow. Because of the possibility of contamination at the outflow site from the waterfowl population, bacteria counts observed for lake site 5 were used to assess the effects of the impoundment on the sanitary bacteria population.

Table 12 is a compilation of the physical, chemical, and bacteriological data collected for both the inflow and outflow area.

Temperature - Water temperatures were nearly the same at both the inflow and outflow; maximum difference was 5.0°C. The incorporation of multiple intake levels in the dam structure provided the capability to regulate the temperature of the outflow. The policy of the Corps of Engineers is to regulate the temperature so that it closely coincides with the water temperature of the Juniata River at the confluence of the Raystown Branch Juniata River and the Juniata River, 8.8 km downstream from Raystown Dam.

pH - The pH at the inflow and outflow ranged from 6.0 to 8.2, which was consistent with the pH measured throughout the lake. The carbon dioxide-bicarbonate-carbonate system caused pH changes as water passed through the lake, but the total effect of the impoundment on the downstream pH was insignificant.

Table 10.--Fecal coliform densities observed for all bacteria sampling sites. (Colonies per 100 milliters. Symbol <, less than.)

Date	Site 1 (Inflow)	Site 2	Site 3	Site 4	Site 5	Site 6 (outflow)	Site 2A	Site 3B	Site 4C
5-14-74		960	10	<1	<1				
5-15-74	210					8			
7-15-74	4					7			
7-16-74		<1	<1	<1	<1				
9-19-74		<1	<1	<1	<1				
9-20-74	21					73			
11-19-74	33					<1			
11-20-74		2	4	1	<1				
1-07-75	67					<1			
1-08-75		170	18	<1	<1				
3-20-75		530	1	<1	<1	<1			
3-21-75	320								
5-20-75	68					<1			
5-21-75		6	<1	<1	<1				
7-22-75	10					3			
7-23-75		<1	<1	<1	<1				
9-23-75	190					11			
9-24-75		2	<1	<1	<1				
11-19-75	180	190				4			
11-20-75			26	<1	<1				
3-02-76	41					<1			
3-03-76		<1	<1	<1			2	<1	2
5-11-76	23				<1	2			
5-12-76		<1	<1	<1			2	<1	<1
6-16-76		<1	56				3	<1	
7-20-76	130	<1	1			2	<1	<1	4
7-21-76				2	<1				
8-17-76	390			1	1	2			
8-18-76		1	2				<1	1	
9-28-76	590			<1	1	2			1
9-29-76		1	<1				<10	<1	

Table 11.--Fecal Streptococcus densities observed for all bacteria sampling sites. (Colonies per 100 milliliters. Symbol <, less than.)

Date	Site 1 (Inflow)	Site 2	Site 3	Site 4	Site 5	Site 6 (outflow)	Site 2A	Site 3B	Site 4C
5-14-74		480	4	<1	<1				
5-15-74	100					37			
7-15-74	48					60			
7-16-74		8	2	3	4				
9-19-74		16	<1	1	2				
9-20-74	24					540			
11-19-74	44					5			
11-20-74		<1	8	<1	<1				
1-07-75	37					2			
1-08-75		193	58	<1	1				
3-20-75		16,000	27	1	<1	1			
3-21-75	420								
5-20-75	29					<1			
5-21-75		2	<1	<1	<1				
7-22-75	81					26			
7-23-75		<1	<1	4	1				
9-23-75	580					140			
9-24-75		4	12	10	16				
11-19-75	36	53				4			
11-20-75			14	<1	<1				
3-02-76	18					<1			
3-03-76		<1	4	5			2	2	3
5-11-76	45				<1	6			
5-12-76		<1	1	1			2	<1	<1
6-15-76	80			<1	<1	10			20
6-16-76		<1	6				3	2	
7-20-76	15	<1	<1			36	2	1	19
7-21-76				8	6				
8-17-76	84			1	2	16			<1
8-18-76		1	2				2	2	
9-28-76	760			1	<1	TNTC*			<1
9-29-76		2	2				14	<1	

* Too numerous to count.

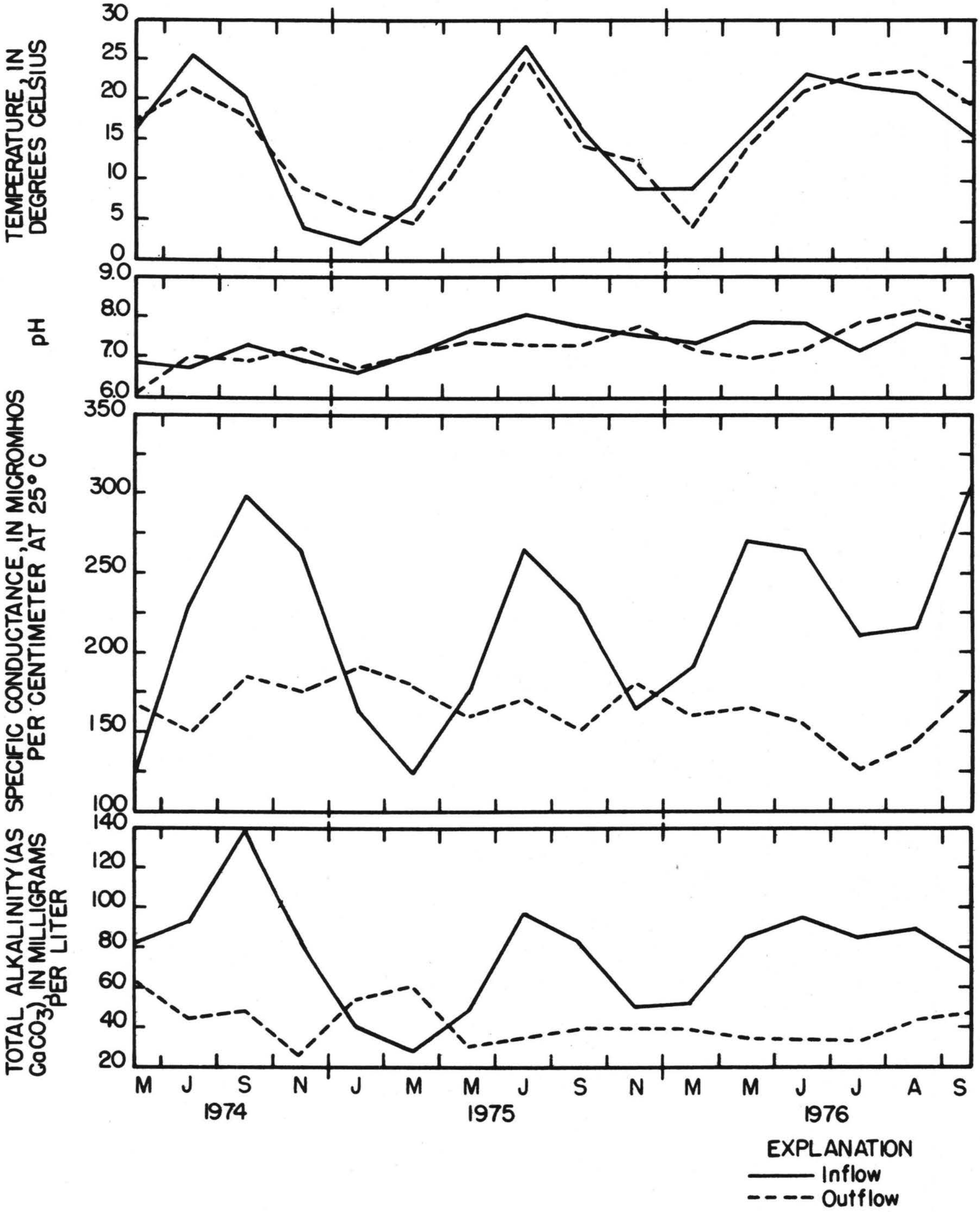

Figure 8.--Physical, chemical, and bacteriological data for the inflow and outflow.

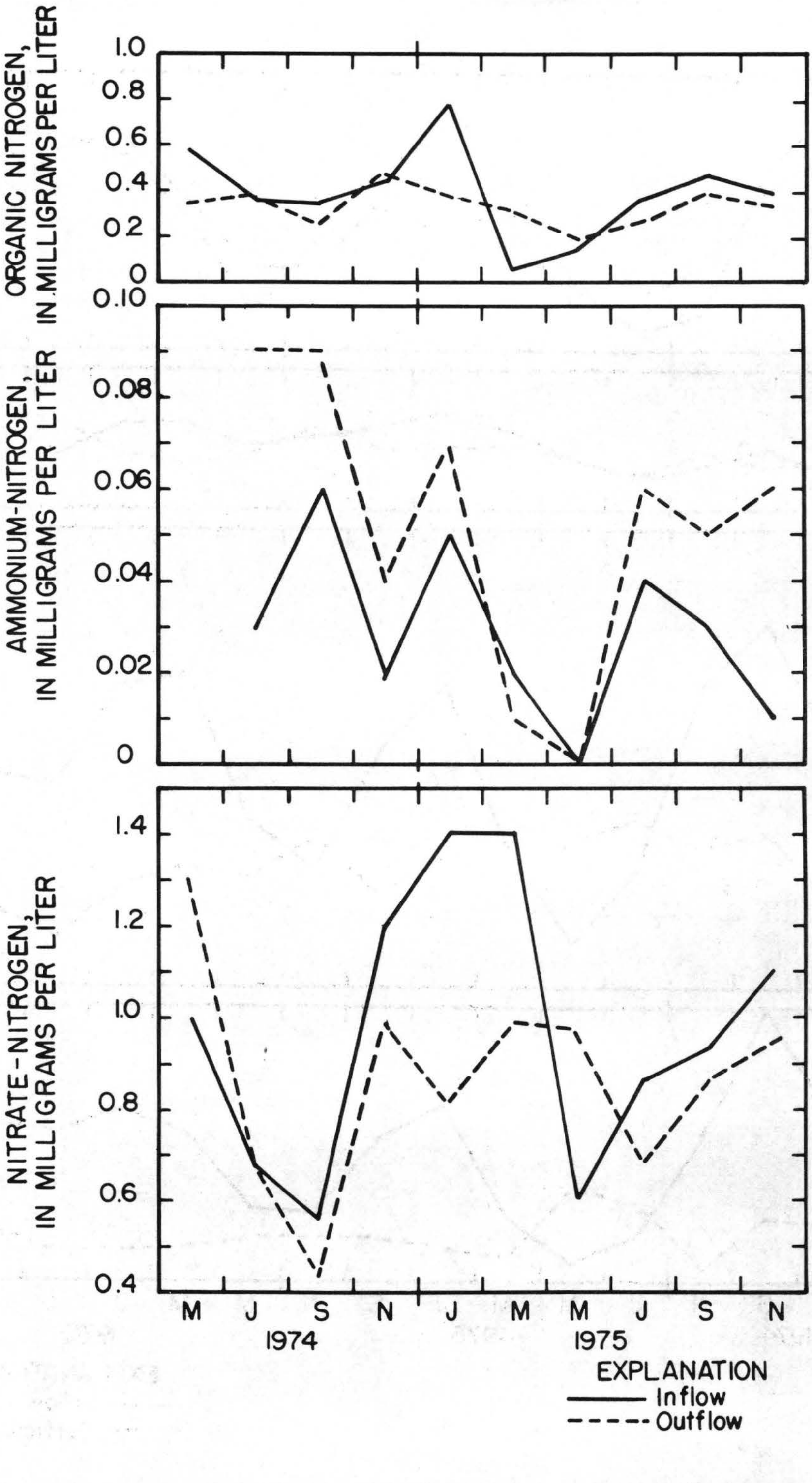

Figure 8.--Physical, chemical, and bacteriological data for the inflow and outflow--Continued

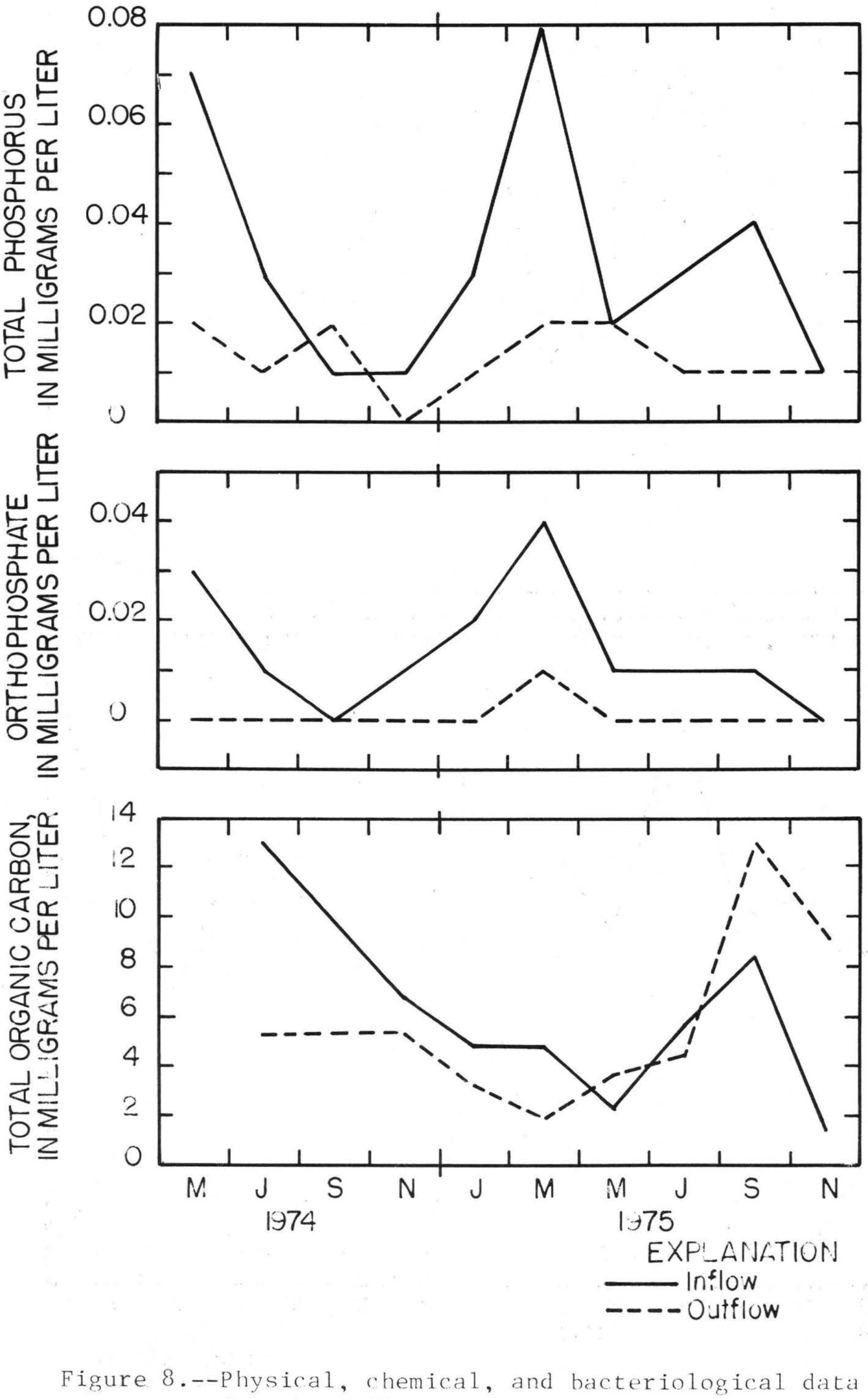

Figure 8.--Physical, chemical, and bacteriological data for the inflow and outflow--Continued

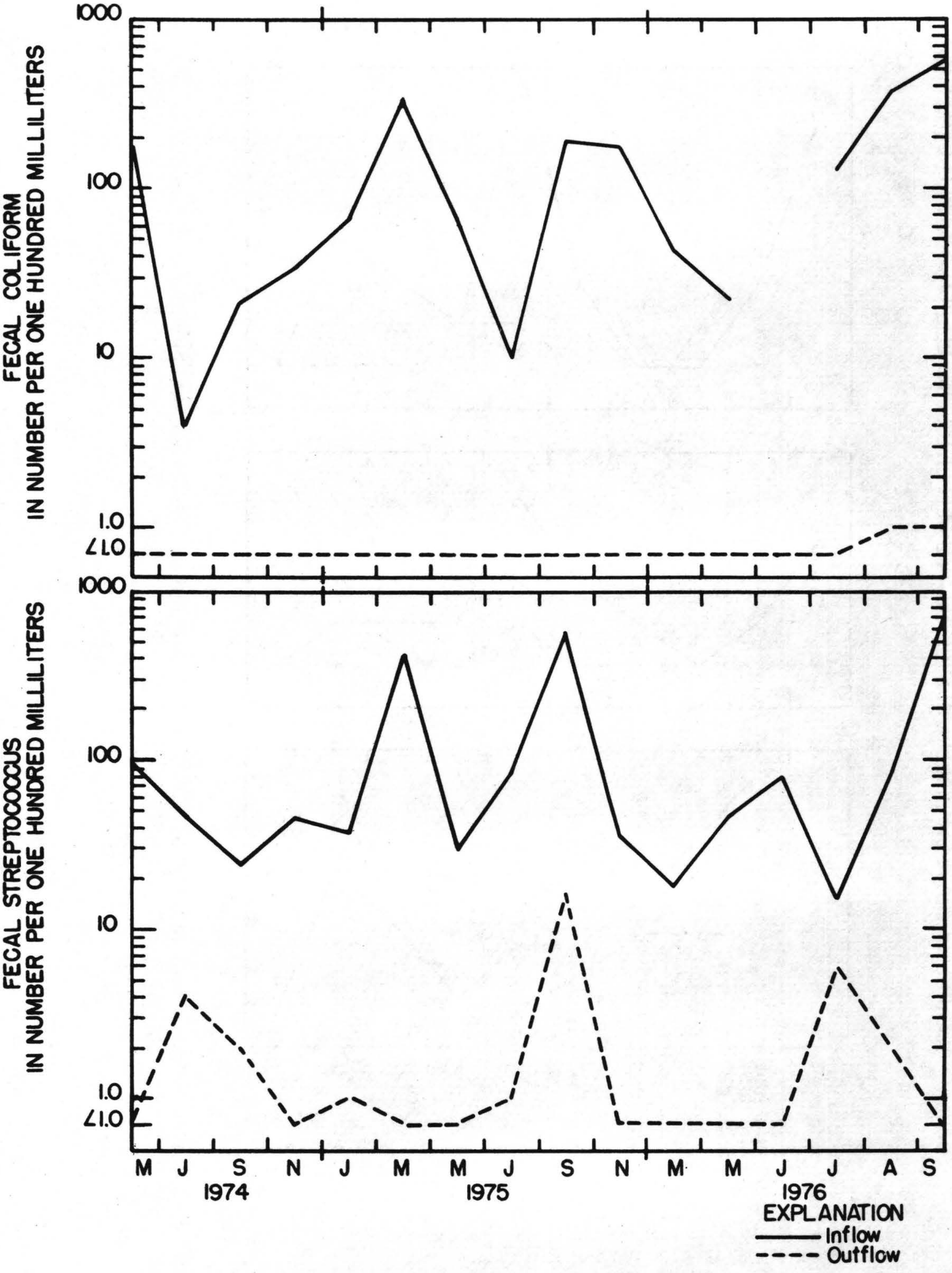

Figure 8.--Physical, chemical, and bacteriological data for the inflow and outflow--Continued

Table 12.--Physical, chemical and bacteriological data for inflow and outflow
(Chemical analyses in milligrams per liter, except as noted.)

Date	Time	Discharge (m^3/s)	Temperature (°C)	pH	Specific conductance (micromhos per cm at 25°C)	Dissolved oxygen	Oxygen saturation (percent)	Total alkalinity	Fecal coliform (no/100 mL)	Fecal streptococcus (no/100 mL)	Organic nitrogen	Ammonium Nitrogen (N)	Nitrate nitrogen (N)	Orthophosphate (P)	Total phosphorus (P)	Total organic carbon
01562000 Raystown Branch Juniata River at Saxton, Pa. (inflow)																
5-15-74	1130	43.3	16.5	6.8	120	9.0	91	81	210	100	0.58	0.18	1.0	0.03	0.07	-
7-15-74	1430	7.6	25.5	6.7	230	8.0	96	93	4	48	.37	.03	.68	.01	.03	13.0
9-20-74	1200	4.1	20.0	7.3	298	11.1	121	120	21	24	.34	.06	.56	.00	.01	-
11-19-74	1200	7.4	4.0	6.9	265	13.3	101	84	33	44	.45	.02	1.2	.01	.01	6.8
1-07-75	1130	25.3	2.0	6.6	165	13.3	96	40	67	37	.79	.05	1.4	.02	.03	4.8
3-21-75	1030	185	7.0	7.1	125	11.7	96	28	320	420	.06	.02	1.4	.04	.08	4.8
5-20-75	1215	34.3	18.0	7.7	197	9.4	99	48	68	29	.15	.00	.61	.01	.02	2.3
7-22-75	1400	7.4	27.0	8.1		10.0	124	97	10	81	.38	.04	.86	.01	.03	5.6
9-23-75	1215	11.4	16.5	7.8	230	10.0	102	82	190	580	.48	.03	.93	.01	.04	8.4
11-19-75	1230	24.8	9.0	7.6	165	11.6	100	50	180	36	.40	.01	1.1	.00	.01	1.4
3-02-76	1030	22.6	9.0	7.4	190	10.8	97	52	41	18						
5-11-76	1030	7.7	16.0	7.9	270	8.0	80	85	23	45						
6-15-76	1015	5.6	23.5	7.9	265	8.6	100	95	-	80						
7-20-76	0930	9.4	22.0	7.2	210	8.5	96	85	130	15						
8-17-76	1000	12.9	21.0	7.9	215	9.2	102	89	390	84						
9-28-76	1030	7.8	16.0	7.7	305	9.8	98	72	590	760						

05632000 Raystown Branch Juniata River below Raytown Dam (outflow)

5-15-74	0930	3.1	17.5	6.0	168	8.2	85	65	8	37	0.34	0.12	1.3	0.00	0.02	-
7-15-74	1200	4.0	21.5	7.0	150	8.8	99	44	7	60	.38	.09	.68	.00	.01	5.3
9-20-74	1000	6.1	18.0	6.9	185	9.2	96	48	73	540	.26	.09	.49	.00	.02	-
11-19-74	1400	3.5	9.0	7.2	175	12.0	104	24	1	5	.48	.04	.99	.00	.00	5.4
1-07-75	1400	32.9	6.0	6.7	190	12.0	96	54	1	2	.39	.07	.81	.00	.01	3.3
3-20-75	2000	340	4.5	7.1	180	13.3	103	60	1	1	.32	.01	.99	.01	.02	1.9
5-20-75	1400	36.2	14.5	7.4	160	11.0	107	31	1	1	.19	.00	.97	.00	.02	2.6
7-22-75	1230	13.6	25.0	7.3	-	8.4	100	35	3	26	.27	.06	.68	.00	.01	4.4
9-23-75	1330	49.8	14.5	7.3	150	11.0	107	39	11	140	.40	.05	.86	.00	.01	13.0
11-19-75	1645	21.5	12.5	7.8	180	10.6	99	39	4	4	.35	.06	.94	.00	.01	9.4
3-02-76	1300	37.1	4.0	7.2	160	13.2	100	39	1	1						
5-11-76	1245	14.5	14.5	7.0	165	10.2	99	34	2	6						
6-15-76	1245	14.1	21.5	7.2	155	9.6	108	33	-	10						
7-20-76	1045	13.8	23.5	7.9	125	9.0	105	33	2	36						
8-17-76	1115	13.8	24.0	8.2	142	10.0	116	43	2	16						
9-28-76	1030	13.5	20.0	7.8	175	-	-	46	2	TNTC*						

* TNTC Too numerous to count.

Specific conductance - The specific conductance at the inflow was generally higher than the specific conductance at the outflow. Raystown Lake stores much of the above-normal flows, which are low in dissolved solids and have low specific conductances; thus, the great storage capacity of the lake contributes to the low specific conductance of the outflow. Biological growth processes in the lake extracted nutrients from the water, and these processes also decreased the specific conductance. Raystown Lake tended to stabilize seasonal fluctuations in the specific conductance measured at the inflow. This was expected because storage reservoirs generally have an equalizing, or smoothing, effect on mineral concentrations (Churchill, 1958, p. 456).

Alkalinity - The impoundment had the same general effect on alkalinity as it had on specific conductance. It reduced the total alkalinity considerably and suppressed its seasonal fluctuations.

Dissolved oxygen - The effect that the impoundment had on the dissolved oxygen concentration cannot be accurately evaluated by comparing concentrations at the inflow and outflow, because water released through the outflow chute was aerated. However, all measured dissolved oxygen concentrations for both the inflow and outflow were near saturation which suggests that the impoundment had no detrimental effect on dissolved oxygen content.

Nitrogen - The fluctuation in the organic nitrogen concentration at the inflow was greater than the fluctuation at the outflow. There was also a slight decrease in the organic nitrogen concentration at the outflow.

Ammonium-N concentrations at the outflow were greater than concentrations at the inflow in seven out of nine corresponding samples.

The impoundment caused a decrease in the nitrate-N concentration between inflow and outflow. The phytoplankton removed the nitrate-N faster than it was replenished by runoff, rainfall, and nitrogen fixation.

Phosphorus - The impoundment had a significant effect on the removal of phosphorus from the water. The total-phosphorus concentrations determined for the inflow exceeded those for the outflow in 7 out of 10 corresponding samples. Orthophosphate was present in 80 percent of the samples collected at the inflow, but only in 10 percent of the samples collected at the outflow. The uptake of orthophosphate by phytoplankton and possibly by other forms of aquatic vegetation and the loss of orthophosphate to the lake sediments almost completely eliminated this ion from the lake waters.

Total organic carbon - Total-organic-carbon concentrations of the inflow were generally greater than those of the outflow. Through oxidation, decomposition, and settlement of organic matter, the organic carbon was gradually lost to the lake sediments. On November 19, 1975, the total-organic-carbon concentration at the outflow was almost seven times greater than that of the inflow. The shore of Raystown Lake is nearly 80 percent forested; it is postulated that dead-leaf litter contributed more than anything else to the high total-organic-carbon concentration at the outflow on this date.

Bacteria - Observed fecal-coliform densities of the surface waters at lake site 5 did not exceed 1 colony per 100 mL, and the maximum fecal-streptococcus density was 16 colonies per 100 mL. The presence of fecal coliform and fecal streptococcus bacteria at the outflow was essentially eliminated, owing to the long retention time in the lake[3/] and the rapid die-off rate of these bacteria.

SUMMARY

The physical, chemical, and biological measurements taken during the study period indicate that Raystown Lake is of good quality and can support a balanced and diverse plant and animal population. Profile measurements that included temperature, dissolved oxygen, pH, and specific conductance were used to describe some initial limnological features of the lake.

Raystown Lake is thermally stratified during summer, particularly from July to September. Inverse thermal stratification was observed in January 1975, and will very likely occur annually while the lake surface is frozen. The lake was generally homothermous during November and March.

Dissolved-oxygen concentrations remained relatively high throughout the vertical water column at sites 4 and 5, except for the metalimnic oxygen minimums measured in July, September, and November, 1975, and August and September 1976. On a few occasions, there was a marked decline in the hypolimnic dissolved oxygen concentrations at sites 2 and 3.

Measured pH in Raystown Lake was between 6.5 and 8.5. Vertically distributed variations in pH were attributed mainly to carbon dioxide-bicarbonate-carbonate reactions.

Specific conductance generally decreased from the lake surface to the lake bottom.

A diel study conducted at site 4 on July 20 and 21, 1976 showed very little change in temperature, dissolved oxygen, pH, and specific conductance of the surface and throughout the vertical.

Alkalinity measurements taken at the inflow, outflow, and of the lake surface indicated the water had a high buffering capacity, particularly at the inflow site.

Nutrient analyses, which included nitrogen and phosphorus compounds, conducted on surface and bottom waters indicated that surface concentrations of organic nitrogen, nitrate nitrogen, total phosphorus, and orthophosphate decreased from site 2 to site 5. Bottom concentrations of nitrate nitrogen increased from site 2 to site 5. Average concentrations of ammonium, orthophosphate and total phosphorus were found to be greater at the bottom than at the surface.

3/ Theoretically, a complete exchange of water will take place in Raystown Lake every 229 days, based on an average annual inflow of $32 m^3/s$.

Light transmission gradually increased from site 2 to site 5, as indicated by Secchi disc transparencies. This was attributed mainly to the settlement of suspended-sediment particles and a decrease in phytoplankton growth.

Concentrations of metallic ions in the lake bottom water near the dam and at the tunnel outflow indicated no toxic levels present.

Algal assays conducted on the surface waters indicated that orthophosphate was a growth-limiting nutrient, and nitrate nitrogen became growth limiting when sufficient orthophosphate was present.

A gradual decrease in chlorophyll *a* concentrations from site 2 to site 5 indicated a decline in lake productivity from inflow to outflow.

Plankton sampling during the study period was insufficient to gain a thorough understanding of the distribution, diversity, and concentration of plankton populations in Raystown Lake. Diatoms were the most frequently collected group of phytoplankton. Qualitative analyses indicated that *Asterionella* and *Dinobryon* were the co-dominant genera present in most of the samples. Only rarely did the total phytoplankton cell count exceed 100 cells/mL. Few zooplankton were observed in the study period.

Most samples at the lake sites had very low densities of both fecal coliform and fecal streptococci bacteria. Most fecal coliform counts were within the limits established by the Pennsylvania Department of Environmental Resources for water-contact recreation.

The most significant effect of the impoundment on water quality was the reduction in concentration of organic nitrogen, nitrate nitrogen, total phosphorus, orthophosphate, and total organic carbon. Ammonium concentrations were greater at the inflow than at the outflow. Specific conductance and alkalinity decreased between inflow and outflow; also, the impoundment stabilized the seasonal fluctuations observed for the inflow. Fecal coliform and fecal streptococci bacteria were essentially eliminated from the lake due to the long retention time of the water and the characteristically rapid die-off rate of these enteric bacteria. Spatial differences were measured in temperature, dissolved oxygen, and pH throughout the lake, but comparison of inflow and outflow data showed that the overall effect of impoundment on these three parameters was insignificant.

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GLOSSARY OF SELECTED TERMS

Aerate (v). To charge or treat with air or other gases, usually with oxygen.

Algae (n), algal (adj). A group of simple primitive plants that live in wet or damp places, and generally are microscopic in size, containing chlorophyll and lacking roots, stems, and leaves.

Aliquot (n). An equally divided portion of a whole sample.

Assay (n). Quantitative estimation of active substances by the amount of their actions in standardized conditions on living organisms or parts of organisms.

Bed material (n). Lake bottom or stream bottom substance, usually consisting of a combination of clay, silt, sand, gravel, boulders, or solid rock.

Biomass (n). The weight of all life in a specified unit of environment. An expression dealing with the total mass or weight of a given community.

Blue-green algae (n). A group of algae with a blue pigment, in addition to the green chlorophyll. Blue-green algae are the group that usually causes nuisance conditions in water.

Decomposition (n). The breakdown of the dead plant and animal tissue by bacteria to the elemental state.

Dendritic (adj). A geometrically shaped body of water that is highly branched or has many arms.

Diatom (n). A group of algae that are characterized by the presence of silica in the cell walls, which are sculptured with striae and other markings, and by the presence of brown pigment associated with the chlorophyll.

Diel (adj). Periodic measurements taken throughout a 24-hour period.

Dimictic (n). A lake in which two overturns take place each year--in spring and autumn; thermal stratification is inverse in winter and direct in summer; typical of lakes in the temperate zone and in higher altitudes in subtropical regions.

Dinoflagellate (n). Typically a unicellular alga that swims by means of two laterally attached appendages called flagella.

Ecosystem (n). An ecological system - the interaction of a group of living organisms with their environment and the exchange of matter and energy between the living and the nonliving.

Enteric (adj). Living within the intestinal tract.

Epilimnion (n). The upper relatively warm, circulating zone of water in a thermally stratified lake.

Euphotic zone (n). That region in a body of water in which there is sufficient light penetration for photosynthetic activity.

Fecal coliform (n). A bacteria group that thrives in the intestines of warm-blooded animals, and is used as an indicator organism for recent fecal contamination.

Fecal streptococcus (n). A bacteria group that thrives in the intestines of warm-blooded animals, particularly livestock and poultry, and is used as an indicator organism for recent fecal contamination.

Green algae (n). Algae that have pigments similar in color to those of higher green plants. Some forms produce algal mats or floating "moss" in lakes.

Genus, genera (n). The taxonomic category consisting of species, and the first part of the scientific name of organisms.

Growth (n). The increase in biomass by synthesis of living matter.

Homothermous (adj). Same water temperature throughout all depths of the lake.

Hypolimnion (n). The lower, relatively cold, noncirculating water zone in a thermally stratified lake.

Ion (n). An electrically charged atom or group of atoms that results from the loss or gain of one or more electrons: the loss of electrons results in a positively charged ion (cation), the gain of electrons is a negatively charged ion (anion).

Limnetic zone (n). The euphotic zone of the open-water region of the lake.

Limnological (adj). The physical, chemical, and biological aspects of inland waters.

Littoral area (n). The shoreward region of a body of water where there is sufficient light transmitted to support attached vegetation.

Metalimnion (n). The middle layer of water in a thermally stratified lake, in which temperature decreases rapidly with depth.

Microcrustacean (n). Microscopic animals of the class Crustacea which occur in the plankton of fresh and marine waters.

Microorganism (n). An organism that is invisible or barely visible to the unaided eye.

Nitrogen fixation (v). The process that transforms elemental nitrogen into forms of nitrogen that can be used by plants in protein synthesis.

Nutrient (n). Any chemical element, ion, or compound that is required by an organism for the continuation of growth, reproduction, and other life processes.

Oligotrophic (n). Waters of low nutrient content which characteristically have little organic production.

Organism (n). Anything that is alive; that is, respiring.

Overturn (n). The process in which lake waters become completely mixed.

Oxidation (n). The process in which oxygen is added to a substance or in which an element loses electrons.

Photosynthesis (n), photosynthetic (adj). A process whereby green plants utilize light as an energy source and convert chemical compounds to carbohydrates. In the process, carbon dioxide is utilized and oxygen is released.

Phytoplankton (n). Plant microorganisms, such as certain algae, living unattached in the water.

Plankton (n). The community of suspended or floating organisms that drift passively with water currents.

Productivity (n). The total amount of organic matter produced from raw materials in an area per unit time.

Reduction (n). The process in which oxygen is lost from a substance, or in which an element gains electrons.

Rotifer (n). A group of many-celled, microscopic, aquatic invertebrate animals of the zooplankton.

Secchi disc (n). A circular metal plate, 20 centimeters in diameter, the upper surface of which is divided into four equal gradrants and so painted that two quadrants directly opposite each other are black and the intervening ones white.

Sediment (n). Fragmental material, both mineral and organic, that is in suspension or is being transported by the water mass or has been deposited on the bottom of the aquatic environment.

Seston (n). The mass of various living and nonliving substances in the water.

Specific conductance (n). A measure of the ability of a water to conduct an electrical current and is expressed in micromhos per centimeter at 25°C.

Taxonomic (adj). Having to do with the classification and naming of organisms.

Trophic state (n). Having to do with nutritional status (i.e., stage of eutrophication).

Trophogenic zone (n). The surficial stratum of a lake in which organic production from mineral substances takes place on the basis of light energy.

Tropholytic zone (n). The deeper parts of a lake, where organic decomposition predominates because of light deficiency.

Zooplankton (n). Animal microorganisms living unattached in water.

VERTICAL PROFILE DATA

(See Table 1 and Figure 1 for names and locations of sites.)

Site 2,
May 14, 1974--1645 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	16.0	9.5	190	7.3
1.0	14.0	9.4		
2.0	14.0	9.3		
3.0	13.5	9.2		
4.0	13.5	9.2		
5.0	13.0	9.0		
6.0	13.0	8.8		
7.0	13.0	8.6		
8.0	12.5	7.4		
8.7	11.0	7.0	220	7.1

Site 2,
July 16, 1974--1600 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	26.5	9.2	190	7.6
1.0	26.5	8.8		
2.0	26.0	8.6		
3.0	26.0	4.6		
4.0	24.5	3.6		
5.0	24.0	3.2		
6.0	23.0	2.8		
7.0	22.0	2.7		
8.0	21.0	1.8		
9.0	19.5	1.5		
10.0	18.0	1.1		
11.0	17.0	0.4		
12.0	15.0	0.3		
13.0	13.0	0.2		
14.0	13.0	0.7	225	7.9

Site 2,
September 19, 1974--1530 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	22.0	8.1	255	7.8
1.0	22.0	7.9		
2.0	22.0	7.8		
3.0	22.0	8.1		
4.0	22.0	8.1		
5.0	21.5	7.9		
6.0	21.5	7.7		
7.0	21.0	7.2		
8.0	21.0	7.2		
9.0	20.5	4.6		
10.0	20.0	1.0		
11.0	16.0	0.3		
12.0	15.0	0.2		
13.0	14.0	0.2		
13.6	13.5	0.2	255	7.8

Site 2,
November 20, 1974--1300 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	8.5	10.9	240	6.7
1.0	8.5	11.0		
2.0	8.5	10.9		
3.0	9.0	10.8		
4.0	8.5	10.8		
5.0	8.5	10.4		
6.0	8.5	10.3		
7.0	8.0	10.0		
8.0	7.0	10.0		
9.0	7.0	9.8		
10.0	6.5	9.8		
11.0	6.5	9.8		
12.0	5.5	9.9		
13.0	6.0	9.8		
14.0	6.0	9.7	320	6.7

Site 2,
January 8, 1975--1030 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	2.5	13.6	155	6.6
1.0	3.0	13.6		
2.0	3.0	13.4		
3.0	3.5	13.2		
4.0	3.5	12.8		
5.0	4.0	12.6		
6.0	4.0	12.4		
7.0	4.0	12.4		
8.0	4.0	12.0		
9.0	4.0	12.0		
10.0	4.0	11.8		
11.0	4.0	11.6		
12.0	4.0	11.4		
13.0	4.0	11.2		
14.0	4.0	11.0		
16.5	4.0	10.5	200	6.6

Site 2,
March 20, 1975--1730 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	6.5	13.2	150	7.3
1.0	6.5	13.0		
2.0	6.5	13.0		
3.0	6.5	12.8		
7.0	6.5	12.8		
10.0	6.5	12.8		
12.0	6.5	12.8		
14.0	6.5	12.8		
23.0	7.0	11.3	160	7.5

Site 2,
May 21, 1975--1015 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	23.0	10.8	170	7.8
1.0	20.5	11.4		
2.0	19.0	10.6		
3.0	17.0	9.0		
4.0	16.0	8.3		
5.0	14.5	8.2		
6.0	12.5	8.7		
7.0	11.5	8.9		
8.0	11.0	8.9		
9.0	10.0	9.5		
10.0	9.5	9.8		
11.0	8.0	9.8		
12.0	7.5	9.9		
13.0	7.0	9.9		
14.0	6.5	9.9		
19.5	8.5	8.6	170	6.5

Site 2,
July 23, 1975--1540 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	27.3	7.8	219	7.9
2.0	26.2	7.4	209	7.7
3.0	25.4	6.5	195	7.4
4.0	24.9	6.0	192	7.2
5.0	23.0	2.3	209	2.0
6.0	20.6	0.0	199	6.9
7.0	18.4	0.0	191	6.9
8.0	15.0	0.0	165	6.9
9.0	12.5	0.4	141	6.9
10.0	10.3	2.2	142	7.0
11.0	9.7	2.5	144	7.0
12.0	8.9	2.4	147	7.1
13.0	8.6	2.4	149	7.1
14.0	7.6	2.6	151	7.1
15.0	7.5	2.8	151	7.1
16.0	7.0	3.1	151	7.1
17.0	6.7	3.5	150	7.1
18.0	6.5	3.5	150	7.1
19.0	6.5	3.6	149	7.1

Site 2,
September 24, 1975--1145 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	19.0	8.7	245	8.0
1.0	19.0	8.7	248	8.0
2.0	19.2	8.7	247	8.0
3.0	19.2	8.6	247	7.9
4.0	19.2	8.6	245	7.9
5.0	19.1	8.5	247	7.9
6.0	19.1	8.5	245	7.9
7.0	19.1	8.6	245	7.9
8.0	19.0	8.4	245	7.9
9.0	19.0	7.8	246	7.8
10.0	16.5	5.1	242	7.3
10.5	14.5	1.8	210	7.1
11.0	11.2	0.0	173	7.0
12.0	9.5	0.0	163	7.0
13.0	9.5	0.0	160	7.0

Site 2,
September 24, 1975--Cont'd

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
14.0	9.0	0.0	158	7.0
16.0	8.2	0.0	155	7.0
18.0	8.0	0.0	152	7.0
18.5	7.4	0.0	158	7.0

Site 2,
November 19, 1975--1350 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	11.5	8.8	200	7.8
1.0	11.0	8.7	200	7.8
2.0	10.5	8.6	200	7.8
3.0	10.5	8.5	200	7.7
4.0	10.5	8.5	200	7.7
5.0	10.5	8.4	200	7.7
6.0	10.2	8.4	198	7.7
7.0	10.0	8.4	191	7.7
8.0	9.7	8.4	186	7.7
9.0	8.4	8.9	166	7.6
10.0	7.5	9.2	149	7.6
11.0	7.5	9.3	145	7.6
12.0	7.2	9.4	143	7.5
13.0	7.2	9.6	141	7.6
14.0	7.0	9.6	138	7.6
15.0	7.0	9.6	138	7.5
16.5	7.0	9.6	137	7.5

Site 2,
March 3, 1976--1330 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	7.5	11.6	133	7.5
1.0	7.5	11.4	133	7.5
5.0	7.0	11.0	126	7.4
10.0	6.5	11.0	125	7.3
15.0	5.5	10.4	120	7.2
20.0	4.5	10.0	115	7.2

Site 2, May 12, 1976--1400 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	15.0	9.7	195	8.0
1.0	14.6	9.8	190	8.0
5.0	12.0	9.8	162	7.9
10.0	8.0	9.8	145	7.8
15.0	6.6	7.1	146	7.6
20.0	6.0	7.2	143	7.5

Site 2, June 16, 1976--1100 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	24.5	8.2	230	8.0
1.0	23.5	8.4	210	8.0
2.0	23.0	8.4	185	8.0
5.0	19.5	9.2	153	7.8
7.5	15.5	7.4	170	7.4
10.0	14.0	4.4	170	7.2
15.0	7.0	2.4	145	7.1
20.0	6.5	4.2	140	7.0

Site 2, July 20, 1976--1430 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	25.0	9.6	200	8.4
1.0	24.5	9.2	195	8.2
2.0	23.1	8.4	177	7.8
3.0	22.5	7.3	170	7.5
4.0	22.5	6.4	167	7.3
5.0	21.5	3.5	180	7.0
6.0	21.0	2.7	175	6.9
7.0	20.0	1.5	166	6.8
8.0	19.0	0.4	162	6.8
9.0	17.0	1.1	167	6.9
10.0	14.5	1.8	175	7.0
11.0	12.0	0.8	167	7.0
12.0	10.5	0.7	158	7.0
13.0	9.5	0.6	155	7.0
14.0	8.5	0.3	150	7.0
15.0	7.5	0.8	147	7.0
17.0	7.5	1.5	140	7.0
18.2	7.0	1.8	143	7.0

Site 2, August 18, 1976--1300 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	24.5	9.2	200	8.5
1.0	24.5	9.2	200	8.5
2.0	24.0	9.2	200	8.5
5.0	23.5	8.8	205	8.3
6.0	23.0	7.5	205	7.8
7.0	21.0	2.8	195	7.1
8.0	19.5	1.5	190	6.9
9.0	17.5	0.0	188	6.9
10.0	15.0	0.0	178	6.9
15.0	7.5	0.0	152	7.0
20.0	6.5	0.0	150	7.0

Site 2, September 29, 1976--1135 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	18.3	7.0	228	7.8
1.0	18.3	6.8	230	7.7
2.0	18.3	6.8	230	7.7
5.0	18.3	6.6	230	7.7
8.0	18.2	6.4	240	7.6
9.0	16.4	0.5	222	7.1
10.0	13.5	0.0	192	7.0
12.0	10.5	0.0	179	7.0
15.0	8.2	0.0	169	7.0
19.0	7.3	0.0	163	7.0

Site 3, May 14, 1974--1545 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	14.5	10.2	205	7.3
1.0	14.5	10.2		
2.0	14.0	10.0		
3.0	14.0	9.8		
4.0	13.0	9.6		
5.0	12.5	9.6		
6.0	12.5	9.2		
7.0	12.0	9.0		
8.0	11.5	8.7		
9.0	10.0	8.0		
10.0	9.0	7.8		
11.0	8.5	7.6		
12.0	8.0	7.6		
13.0	7.0	6.8		
14.0	7.0	6.8		
16.5			175	7.3

Site 3, July 16, 1974--1440 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	26.0	9.6	175	7.6
1.0	26.0	9.6		
2.0	26.0	9.6		
3.0	26.0	9.0		
4.0	25.0	8.1		
5.0	23.5	8.0		
6.0	22.5	6.0		
7.0	21.5	4.6		
8.0	20.5	3.5		
9.0	19.5	3.4		
10.0	18.0	2.6		
11.0	16.0	0.4		
12.0	15.0	0.6		
13.0	13.5	1.4		
14.0	12.5	1.6		
22.0	10.5	1.2	180	7.9

Site 3, September 19, 1974--1430 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	22.5	8.9	210	7.8
1.0	22.0	8.7		
2.0	22.0	8.7		
3.0	21.5	8.7		
4.0	21.5	8.7		
5.0	21.5	8.6		
6.0	21.5	8.5		
7.0	21.5	8.4		
8.0	21.0	6.8		
9.0	20.0	0.7		
10.0	19.0	0.4		
11.0	17.5	0.4		
12.0	16.0	0.3		
13.0	14.0	0.3		
14.0	13.0	0.3		
21.3	11.0		195	7.8

Site 3, November 20, 1974--1200 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	8.0	10.6	220	6.7
1.0	8.5	10.2		
2.0	8.5	10.0		
3.0	8.5	10.0		
4.0	9.0	9.9		
5.0	9.0	9.6		
6.0	9.0	9.3		
7.0	9.0	8.9		
8.0	9.0	8.1		
9.0	9.0	7.9		
10.0	9.0	7.4		
11.0	9.0	7.2		
12.0	9.0	6.8		
13.0	9.0	6.8		
14.0	9.0	6.6		
20.4	8.5	0.4	200	6.7

Site 3, January 8, 1975--1030 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	2.5	13.0	180	6.9
1.0	3.0	12.8		
2.0	3.0	12.8		
3.0	3.0	12.6		
4.0	3.0	12.6		
5.0	3.0	12.3		
6.0	3.5	12.2		
7.0	3.5	12.0		
8.0	3.5	11.8		
9.0	3.5	11.5		
10.0	3.5	11.5		
11.0	3.5	11.3		
12.0	3.5	11.3		
13.0	3.5	11.2		
14.0	4.0	11.1		
22.6	4.5	10.8	170	7.0

Site 3, March 20, 1975--1645 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	5.0	13.2	140	7.5
1.0	5.0	13.2		
2.0	5.0	13.2		
3.0	5.0	13.2		
7.0	5.0	13.3		
10.0	5.0	13.3		
12.0	5.0	13.3		
14.0	5.0	13.2		
25.0	5.0	11.2	145	7.6

Site 3, May 21, 1975--1130 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	24.0	10.7	140	7.8
1.0	21.0	11.5		
2.0	20.0	12.4		
3.0	18.0	11.9		
4.0	16.0	10.8		
5.0	13.0	9.1		
6.0	12.5	9.1		
7.0	11.5	9.1		
8.0	11.0	9.3		
9.0	10.5	9.3		
10.0	9.5	9.8		
11.0	8.0	10.3		
12.0	7.5	10.7		
13.0	6.5	11.0		
14.0	6.5	11.3		
29.0	7.5	8.4	145	6.6

VERTICAL PROFILE DATA--Continued

Site 3, July 23, 1975--1530 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	26.5	7.6	182	7.8
2.0	25.9	7.6	178	7.8
3.0	25.6	7.6	176	7.7
4.0	25.2	7.5	174	7.6
5.0	23.6	4.8	168	7.0
6.0	21.5	4.5	174	7.0
7.0	18.5	0.8	173	6.9
8.0	15.5	0.3	149	6.8
9.0	11.5	1.4	140	6.9
10.0	10.6	2.6	142	6.9
11.0	9.4	4.2	147	7.0
12.0	8.6	5.2	148	7.1
13.0	7.7	6.2	148	7.1
14.0	7.5	6.4	148	7.1
16.0	6.8	7.1	145	7.1
19.0	6.2	7.0	142	7.1
22.0	5.6	6.3	142	7.0
26.0	5.4	5.6	144	7.0

Site 3, September 24, 1975--1300 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	19.0	8.8	207	8.0
1.0	19.0	8.8	207	7.9
2.0	19.0	8.8	207	7.9
3.0	19.0	8.8	208	7.9
4.0	19.0	8.8	208	7.9
5.0	19.0	8.7	208	7.9
6.0	19.0	8.7	208	7.9
7.0	19.0	8.7	208	7.9
8.0	19.0	8.6	209	7.9
8.5	18.4	4.0	208	7.1
9.0	14.1	0.3	160	6.8
10.0	11.0	0.3	146	6.7
12.0	8.8	0.0	148	6.8
14.0	7.5	1.5	145	6.9
16.0	7.0	3.2	142	6.9
18.0	6.2	2.6	143	6.9
20.0	6.2	2.3	143	6.9
22.0	6.0	2.0	143	6.8
24.0	6.0	1.8	143	6.8
28.0	6.0	0.1	160	6.9

Site 3, November 20, 1975--1500 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	11.5	8.7	153	7.5
1.0	11.2	8.4	152	7.6
2.0	11.0	8.3	153	7.5
3.0	10.8	8.1	153	7.5
4.0	10.8	8.0	152	7.5
5.0	10.7	8.0	152	7.5
6.0	10.7	8.0	152	7.5
7.0	10.6	7.9	152	7.5
8.0	10.6	7.7	152	7.4
9.0	10.6	7.5	150	7.3
11.0	10.0	7.2	151	7.2
13.0	9.4	6.7	180	7.3
14.0	9.0	6.2	170	7.3
15.0	8.6	5.2	168	7.1
16.0	8.4	4.2	166	7.0
17.0	8.0	2.5	159	6.8
18.0	7.5	1.2	154	6.8
20.0	7.0	0.5	148	6.7
22.0	6.6	0.2	148	6.7
24.0	6.5	0.2	148	6.7

Site 3, March 3, 1976--1130 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	5.5	11.0	120	7.4
1.0	5.5	11.0	121	7.4
5.0	5.5	11.0	120	7.3
10.0	5.0	10.9	120	7.3
15.0	4.7	11.0	125	7.3
20.0	4.3	11.2	130	7.3
25.0	3.9	10.8	135	7.3
27.5	3.6	10.6	138	7.3

Site 3, May 12, 1976--1200 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	13.5	10.3	164	7.9
1.0	13.6	10.1	165	7.8
5.0	13.4	10.1	158	7.8
10.0	8.0	9.5	145	7.7
15.0	6.0	9.0	144	7.6
20.0	5.5	8.7	142	7.6
25.0	5.4	8.5	144	7.5
27.5	5.3	8.4	143	7.4

Site 3, June 16, 1976--1000 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	23.5	8.1	169	7.9
2.0	23.0	8.1	172	7.9
5.0	19.0	8.8	148	7.6
7.5	15.0	8.3	148	7.5
10.0	13.0	6.7	149	7.3
12.5	9.0	6.0	142	7.2
15.0	7.5	6.0	137	7.2
20.0	6.0	6.3	135	7.2
27.5	5.5	6.0	134	7.1

Site 3, July 20, 1976--1545 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	24.0	9.3	160	8.4
1.0	24.0	9.2	162	8.3
3.0	23.0	9.5	160	8.3
5.0	22.0	7.6	160	7.6
6.0	21.5	6.0	172	7.2
7.0	21.0	4.4	165	7.0
8.0	19.0	1.1	155	6.8
9.0	16.5	3.0	163	7.0
10.0	14.0	4.3	153	7.0
12.0	11.0	4.0	149	7.0
15.0	7.5	4.6	138	7.0
20.0	6.0	5.2	135	7.1
25.0	5.5	4.9	135	7.1
27.9	5.5	4.7	135	7.0

Site 3, August 18, 1976--1030 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	23.5	8.5	172	8.2
1.0	23.5	8.5	172	8.1
2.0	23.5	8.4	172	7.9
5.0	23.0	8.2	172	7.9
6.0	23.0	8.1	174	7.8
6.5	22.0	2.2	180	6.8
7.0	21.5	0.9	192	6.9
8.0	19.5	1.4	172	6.7
9.0	17.0	0.2	168	6.8
10.0	15.0	1.7	158	6.9
11.0	13.0	2.0	156	6.9
15.0	8.0	2.8	146	7.0
20.0	6.0	3.8	145	7.1
27.0	5.5	3.4	145	7.1

Site 3, September 29, 1976--1000 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	17.5	8.2	195	7.8
1.0	18.0	8.0	195	7.7
2.0	18.0	7.2	192	7.6
5.0	18.0	7.1	192	7.6
8.0	18.0	7.1	192	7.6
9.0	16.5	1.3	170	7.0
10.0	13.5	0.8	170	6.7
12.0	10.5	0.7	160	6.8
15.0	8.0	1.6	152	6.9
20.0	6.5	1.6	150	6.9
25.0	6.5	1.3	152	7.0
28.0	5.5	1.1	152	6.9

Site 4 May 14, 1974--1810 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	13.5	10.0	162	7.4
1.0	13.5	10.0		
2.0	13.5	9.8		
3.0	13.5	9.8		
4.0	13.5	9.8		
5.0	13.5	9.7		
6.0	13.3	9.7		
7.0	13.0	9.5		
8.0	13.0	9.4		
9.0	12.0	9.2		
10.0	11.0	9.2	175	7.2
11.0	11.0	8.6		
12.0	9.0	8.6		

Site 4, July 16, 1974--1330 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	27.0	8.7	160	7.3
1.0	26.5	8.7		
2.0	26.5	8.7		
3.0	26.0	8.6		
4.0	26.0	8.6		
5.0	25.5	9.2		
6.0	24.0	9.2		
7.0	23.0	7.5		
8.0	22.0	4.2		
9.0	19.5	2.4		
10.0	18.0	1.0		
11.0	17.0	2.6		
12.0	15.0	4.0		
13.0	13.0	4.2		
14.0	11.5	4.6		
38.0	10.0	4.6	180	7.4

Site 4, September 19, 1974--1330 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (μmhos at 25°C)	pH
0.5	22.5	8.8	180	7.3
1.0	22.0	8.7		
2.0	22.0	8.7		
3.0	22.0	8.7		
4.0	22.0	8.6		
5.0	22.0	8.6		
6.0	22.0	8.6		
7.0	22.0	8.6		
8.0	22.0	8.5		
9.0	21.0	7.5		
10.0	19.5	0.6		
11.0	17.0	0.5		
12.0	15.0	0.6		
13.0	13.5	1.4		
14.0	12.0	2.0		
32.9	9.5		200	7.6

Site 4, November 20, 1974--1100 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	9.5	9.8	170	6.8
1.0	9.5	9.7		
2.0	9.0	9.6		
3.0	9.0	9.5		
4.0	9.0	9.4		
5.0	9.0	9.4		
6.0	9.0	9.0		
7.0	9.0	9.0		
8.0	9.0	9.2		
9.0	9.0	9.2		
10.0	9.0	9.1		
11.0	8.5	9.0		
12.0	8.5	9.0		
13.0	8.5	9.0		
14.0	8.5	9.0		
33.5	7.0	0.4	180	6.7

Site 4, January 8, 1975--1415 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	6.0	10.6	170	7.1
1.0	6.0	10.6		
2.0	6.0	10.6		
3.0	6.0	10.6		
4.0	6.0	10.6		
5.0	6.0	10.4		
6.0	6.0	10.4		
7.0	6.0	10.3		
8.0	6.0	10.3		
9.0	6.0	10.2		
10.0	6.0	10.2		
11.0	6.0	10.1		
12.0	6.0	10.1		
13.0	6.0	10.0		
14.0	6.0	10.0		
28.0	5.5	10.5	195	7.0

Site 4, March 20, 1975--1530 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	3.5	13.6	160	7.6
7.0	3.5	13.5		
10.0	3.5	13.4		
14.0	3.5	13.4		
39.0	4.0	11.3	175	7.6

Site 4, May 21, 1975--1300 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	24.0	11.6	120	7.8
1.0	21.5	12.3		
2.0	20.5	12.3		
3.0	19.5	12.2		
4.0	17.0	11.8		
5.0	14.5	10.8		
6.0	12.5	9.8		
7.0	11.5	9.6		
8.0	11.0	10.0		
9.0	10.0	10.8		
10.0	9.0	11.4		
11.0	8.5	11.4		
12.0	8.0	11.8		
13.0	7.0	12.0		
14.0	7.0	12.2		
25.0		9.2	145	6.7
39.0	6.5	10.4	175	6.5

Site 4, July 23, 1975--1405 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	27.1	8.0	156	8.0
2.0	26.2	8.1	156	8.0
3.0	26.0	8.1	154	8.0
4.0	25.8	8.2	151	8.0
5.0	24.4	7.7	148	7.4
6.0	21.6	7.2	145	7.1
7.0	17.4	3.8	138	6.9
8.0	14.2	3.0	130	6.8
9.0	12.0	4.6	136	7.0
10.0	10.5	6.1	140	7.1
11.0	9.0	7.1	142	7.2
12.0	8.0	8.0	143	7.2
13.0	7.5	8.4	141	7.3
14.0	7.0	8.7	139	7.3
16.0	6.4	9.2	138	7.3
19.0	5.9	9.7	137	7.3
22.0	5.1	9.6	137	7.3
27.0	5.2	8.8	138	7.2
32.0	5.1	8.2	142	7.1
38.0	5.0	5.6	149	7.0

Site 4 September 24, 1975--1445 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	19.4	8.6	166	7.9
1.0	19.4	8.6	166	7.8
2.0	19.5	8.5	168	7.9
3.0	19.4	8.5	167	7.8
4.0	19.5	8.5	168	7.8
5.0	19.5	8.4	167	7.8
6.0	19.4	8.4	169	7.8
7.0	19.4	7.8	169	7.5
7.5	19.0	6.6	167	7.3
8.0	14.4	0.0	143	6.7
9.0	11.9	0.0	142	6.7
10.0	10.5	1.4	143	6.8
11.0	9.0	3.0	145	6.9
12.0	8.5	4.0	143	7.0
13.0	7.6	5.0	142	7.0
14.0	7.5	5.5	141	7.0
15.0	7.1	5.7	141	7.0
17.0	6.7	6.3	138	7.1
19.0	6.1	6.6	137	7.1
21.0	6.0	6.6	139	7.1
23.0	5.6	6.1	139	7.1
25.0	5.6	6.0	141	7.0
30.0	5.5	5.4	142	7.0
35.0	5.4	4.8	145	6.9
39.5	5.4	4.4	146	7.2

Site 4, November 20, 1975--1350 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	12.5	8.7	151	7.7
1.0	12.0	8.8	151	7.8
2.0	11.6	8.7	150	7.7
3.0	11.5	8.4	150	7.6
4.0	11.5	8.4	150	7.6
5.0	11.5	8.2	159	7.6
7.0	11.2	7.6	156	7.4
9.0	11.1	7.5	156	7.4
11.0	11.0	7.4	154	7.4
13.0	10.9	7.0	151	7.3
13.5	9.9	4.6	150	7.0
14.0	9.0	3.0	146	6.9
15.0	7.7	3.2	142	6.8
16.0	7.0	3.2	141	6.8
18.0	6.6	3.3	141	6.8
20.0	6.1	3.2	142	6.8
25.0	6.0	2.8	142	6.8
30.0	5.9	2.8	142	6.8
35.0	5.6	3.2	142	6.8
37.5	5.6	3.2	141	6.8

Site 4, March 3, 1976--1000 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	3.2	11.2	155	7.4
1.0	3.2	11.2	155	7.4
5.0	3.2	11.2	156	7.4
10.0	3.2	11.2	154	7.4
20.0	3.2	11.2	153	7.4
30.0	3.2	11.0	153	7.4
35.0	3.2	10.6	152	7.3
41.0	3.2	9.4	155	7.2

Site 4, May 12, 1976--1000 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	13.8	10.1	152	7.9
1.0	13.8	10.1	152	7.9
5.0	13.6	10.0	154	7.8
10.0	12.5	10.0	149	7.8
11.0	11.5			
12.5	7.6			
15.0	7.0	10.1	144	7.8
25.0	5.1	9.5	145	7.7
35.0	4.9	9.5	145	7.6
38.0	4.9	9.4	143	7.5

Site 4, June 15, 1976--1500 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	23.6	8.4	148	8.0
1.0	23.0	8.2	146	8.0
2.0	22.4	8.3	146	8.0
5.0	20.0	9.4	141	8.0
10.0	13.4	9.0	140	7.6
15.0	7.3	8.8	133	7.4
20.0	6.0	8.3	130	7.3
30.0	5.1	8.6	130	7.3
41.5	4.8	7.8	141	7.2

Site 4, July 21, 1976--1200 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	24.5	8.9	167	8.4
1.0	24.5	8.9	164	8.3
3.0	24.5	9.0	157	8.3
5.0	24.0	9.1	157	8.3
7.0	22.5	8.3	157	7.7
10.0	15.5	6.8	147	7.3
20.0	6.5	7.2	132	7.2
30.0	5.5	7.0	135	7.2
35.0	5.0	7.0	137	7.1

Site 4, August 17, 1976--1530 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	25.5	8.4	157	8.4
1.0	25.5	8.7	152	8.3
5.0	24.5	8.7	148	8.4
6.0	23.5	8.7	150	7.8
7.0	22.5	6.7	152	7.0
8.0	20.0	0.2	150	6.8
9.0	17.0	0.2	142	7.1
10.0	14.5	4.0	132	7.2
15.0	8.5	6.0	125	7.3
20.0	7.0	7.0	125	7.4
30.0	5.5	6.9	130	7.3
40.0	5.5	4.2	132	7.1
41.0	5.5	2.4	135	7.1
42.0	5.5	0.4	155	7.2

Site 4, September 28, 1976--1430 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	19.0	7.5	173	7.9
1.0	19.5	7.6	173	7.8
2.0	19.5	7.5	172	7.8
5.0	19.0	7.3	172	7.7
8.0	19.0	7.2	172	7.7
9.0	17.0	3.9	158	7.1
10.0	13.0	3.5	152	7.0
12.0	10.0	3.6	143	6.9
15.0	7.5	5.0	143	7.0
20.0	6.5	5.1	144	7.1
30.0	5.5	4.8	148	7.1
38.0	5.0	3.9	150	7.0
40.0	5.0	3.1	150	7.0

Site 5, May 14, 1974--1400 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	14.0	9.7	170	7.4
1.0	14.0	9.7		
2.0	14.0	9.7		
3.0	14.0	9.7		
4.0	14.0	9.7		
5.0	14.5	9.7		
6.0	13.0	9.7		
7.0	13.0	9.6		
8.0	13.0	9.6		
9.0	13.0	9.5		
10.0	13.0	9.1		
11.0	10.0	9.1		
12.0	9.0	9.1		
13.0	8.0	9.3		
14.0	7.0	9.4		
25.0			180	7.0

Site 5, July 16, 1974--1130 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	26.0	8.7	155	6.9
1.0	26.0	8.7		
2.0	26.0	8.7		
3.0	26.0	8.7		
4.0	25.5	8.7		
5.0	25.0	9.2		
6.0	24.0	9.4		
7.0	23.0	8.6		
8.0	21.0	6.6		
9.0	19.0	7.0		
10.0	17.0	7.6		
11.0	16.0	7.5		
12.0	14.0	6.8		
13.0	13.0	6.6		
14.0	11.0	6.9		
42.0	10.0	7.6	175	7.4

Site 5, September 19, 1974--1200 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	22.0	9.4	165	6.8
1.0	22.0	9.3		
2.0	22.0	9.3		
3.0	22.0	9.3		
4.0	22.0	9.2		
5.0	21.5	9.2		
6.0	21.5	9.1		
7.0	21.5	9.1		
8.0	21.5	9.0		
9.0	21.5	8.9		
10.0	20.0	1.7		
11.0	16.5	2.8		
12.0	15.0	3.6		
13.0	13.0	3.8		
14.0	12.0	5.2		
40.8	7.5	3.0	190	7.0

Site 5, November 20, 1974--0900 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	10.0	11.2	160	6.9
1.0	10.0	11.1		
2.0	10.0	11.0		
3.0	10.0	11.0		
4.0	10.0	10.8		
5.0	10.0	10.8		
6.0	10.0	10.8		
7.0	10.0	10.8		
8.0	10.0	10.8		
9.0	10.0	10.7		
10.0	10.0	10.7		
11.0	10.0	10.6		
12.0	10.0	10.4		
13.0	10.0	10.4		
14.0	10.0	10.2		
29.0	7.0	3.9	150	7.1

Site 5, January 8, 1975--1530 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	6.0	9.9	170	7.0
1.0	6.0	9.9		
2.0	6.0	9.8		
3.0	6.0	9.8		
4.0	6.0	9.7		
5.0	6.0	9.6		
6.0	6.0	9.5		
7.0	6.0	9.5		
8.0	6.0	9.4		
9.0	6.0	9.4		
10.0	6.0	9.3		
11.0	6.0	9.2		
12.0	6.0	9.2		
13.0	6.0	9.2		
14.0	6.0	9.1		
25.0	5.5	9.6		
35.7	5.0	7.5	180	7.1

Site 5, March 20, 1975--1330 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	4.5	13.4	180	7.6
1.0	4.0	13.4		
2.0	4.0	13.6		
3.0	4.0	13.4		
4.0	3.5	13.5		
5.0	3.5	13.5		
6.0	3.5	13.5		
7.0	3.5	13.5		
8.0	3.5	13.5		
9.0	3.5	13.5		
10.0	3.5	13.5		
11.0	3.5	13.5		
12.0	3.5	13.5		
13.0	3.5	13.5		
14.0	3.5	13.5		
30.0		11.6		
46.0		12.0	180	7.6

Site 5, May 21, 1975--1430 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	25.0	10.7	140	7.4
1.0	22.0	11.0		
2.0	21.0	12.0		
3.0	18.0	12.6		
4.0	17.0	12.0		
5.0	15.0	11.4		
6.0	13.0	11.1		
7.0	11.5	10.8		
8.0	11.0	10.8		
9.0	10.0	10.8		
10.0	9.5	11.6		
11.0	8.0	11.8		
12.0	8.0	12.0		
13.0	7.0	12.2		
14.0	6.5	12.5		
40.0		11.2	180	6.7
48.0		11.2	180	6.8

Site 5, July 23, 1975--1230 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	26.6	8.3	145	8.1
1.0	26.5	8.3	145	8.1
2.0	26.1	8.3	145	8.1
3.0	26.0	8.3	145	8.1
4.0	26.0	8.3	146	8.1
5.0	25.7	8.3	147	8.0
6.0	21.7	8.7	140	6.9
7.0	17.2	5.4	136	6.9
8.0	13.6	5.1	138	7.0
9.0	11.6	5.6	140	7.0
10.0	10.2	6.7	141	7.2
11.0	9.0	7.7	142	7.2
12.0	8.0	8.7	141	7.3
13.0	7.5	9.0	140	7.3
14.0	7.1	9.7	140	7.4
16.0	6.5	10.0	140	7.4
19.0	6.0	9.6	144	7.4

Site 5, July 23, 1975--Continued

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
22.0	5.6	10.3	144	7.5
27.0	5.4	10.2	145	7.4
32.0	5.0	9.9	146	7.4
37.0	5.0	9.7	147	7.3
42.0	4.8	9.1	148	7.2
48.0	4.7	8.8	148	7.2

Site 5, September 24, 1975--1645 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	19.5	8.5	153	7.9
1.0	19.5	8.6	156	7.8
2.0	19.5	8.6	156	7.8
3.0	19.5	8.6	156	7.8
4.0	19.0	8.6	156	7.8
5.0	19.0	8.6	156	7.8
6.0	19.0	8.4	156	7.9
6.5	17.5	2.6	150	6.8
7.0	15.0	0.4	140	6.7
8.0	11.5	3.0	140	6.8
10.0	8.5	5.7	140	7.0
12.0	7.5	6.8	138	7.1
14.0	6.5	8.0	138	7.2
16.0	6.5	8.6	138	7.2
18.0	6.0	9.0	140	7.3
20.0	5.7	9.0	141	7.3
25.0	5.5	9.0	142	7.3

Site 5, September 24, 1975--Cont'd

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
30.0	5.5	8.6	144	7.3
35.0	5.2	8.2	144	7.2
40.0	5.0	7.6	144	7.2
45.0	5.0	6.8	146	7.1
46.0	5.0	6.4	146	7.1

Site 5, November 20, 1975--1220 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	12.0	8.2	165	7.6
1.0	12.0	8.2	164	7.6
2.0	12.0	8.1	165	7.6
3.0	12.0	8.1	163	7.5
4.0	12.0	8.0	165	7.5
5.0	11.8	8.0	165	7.5
7.0	11.8	8.0	165	7.5
9.0	11.7	7.6	164	7.4
11.0	11.5	7.6	162	7.4
12.0	11.2	7.6	161	7.4
13.0	9.5	3.0	146	6.8
14.0	8.0	4.2	141	6.8

Site 5, November 20, 1975--Continued

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
15.0	7.0	5.2	139	6.9
16.0	6.7	5.8	139	7.0
17.0	6.5	6.1	139	7.0
18.0	6.2	6.4	139	7.0
20.0	5.9	6.6	141	7.0
22.0	6.0	6.5	141	7.0
24.0	5.7	6.4	142	7.0
29.0	5.5	5.6	143	7.0
34.0	5.3	5.8	143	7.0
39.0	5.2	5.0	145	6.9
43.0	5.2	4.2	146	6.9
46.0	5.2	3.3	149	6.9

Site 5, March 2, 1976--1400 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	3.5	11.2	125	7.5
1.0	3.5	11.2	138	7.4
2.0	3.5	11.1	142	7.4
5.0	3.5	11.1	140	7.4
10.0	3.5	11.1	142	7.4
15.0	3.4	11.0	143	7.4
20.0	3.4	11.0	141	7.4
30.0	3.5	11.0	139	7.4
40.0	3.6	11.0	139	7.4
45.0	3.7	10.2	139	7.4
49.0	3.6	8.2	148	7.2

Site 5, May 11, 1976--1430 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	15.5	10.0	148	8.0
5.0	14.5	10.2	148	8.0
10.0	11.4	10.0	145	7.9
15.0	7.1	10.4	144	7.9
20.0	5.7	10.4	144	7.8
25.0	5.0	10.2	148	7.6
35.0	4.5	10.1	146	7.6
45.0	4.5	10.2	145	7.6
47.5	4.5	10.1	144	7.6

Site 5, June 15, 1976--1330 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	24.7	8.3	150	7.8
1.0	23.1	8.5	150	7.8
2.0	22.6	8.6	149	7.8
5.0	21.5	9.0	152	7.9
10.0	12.7	8.8	142	7.8
15.0	7.6	9.2	132	7.6
20.0	6.1	8.8	135	7.5
30.0	5.1	8.4	138	7.4
40.0	4.8	8.8	136	7.4
44.5	4.6	8.8	141	7.4

Site 5, July 21, 1976--1130 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	24.5	8.9	155	8.4
1.0	24.5	8.8	155	8.3
3.0	24.5	8.9	153	8.2
5.0	24.0	9.0	150	8.3
7.0	22.5	9.4	140	7.7
8.0	17.0	10.9	145	8.0
10.0	14.0	9.2	135	7.5
15.0	8.0	9.1	130	7.4
20.0	6.5	8.9	132	7.4
30.0	5.5	8.6	135	7.4
40.0	5.0	8.8	138	7.3
48.7	5.0	8.7	140	7.2

Site 5, August 17, 1976--1430 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	24.5	8.7	147	8.2
1.0	24.5	8.7	147	8.1
2.0	24.5	8.7	147	8.1
5.0	24.0	8.7	147	8.1
6.0	23.0	9.2		
7.0	21.0	6.4		
7.5	20.0	4.8	146	6.9
10.0	15.0	8.0	133	7.1
15.0	8.0	8.5	125	7.3
20.0	6.5	8.8	127	7.3
25.0	6.0	8.3	128	7.3
30.0	5.5	8.2	129	7.2
35.0	5.5	8.5	129	7.3
40.0	5.3	8.5	129	7.2
49.0	5.3	7.0	158	7.4
50.0	5.3	0.4	132	7.2

Site 5, September 28, 1976--1330 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	19.5	7.6	165	7.8
1.0	19.5	7.4	167	7.7
2.0	19.5	7.4	167	7.7
5.0	19.5	7.4	167	7.6
8.0	19.0	7.2	167	7.6
9.0	14.5	5.8	153	7.1
10.0	12.5	6.2	152	7.1
12.0	9.0	6.5	148	7.1
15.0	7.0	6.5	146	7.2
20.0	6.0	6.7	147	7.2
30.0	5.0	6.4	150	7.2
40.0	5.0	6.3	148	7.2
48.0	5.0	4.2	152	7.1
49.5	5.0	2.0	162	7.2

Site 2A, August 18, 1976--1300 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	25.0	9.0	200	8.4
1.0	24.5	9.1	195	8.4
2.0	24.0	9.1	195	8.3
5.0	23.5	9.0	190	8.2
6.0	23.0	8.4	195	7.9
7.0	22.5	2.8	210	7.4
8.0	19.5	0.0	205	6.8
9.0	16.5	0.2	180	6.9
10.0	14.5	0.3	178	6.9
12.0	10.5	0.3	170	7.0

Site 2A, September 29, 1976--1130 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	18.5	7.1	228	7.8
1.0	18.0	7.0	222	7.7
2.0	18.0	6.8	225	7.7
5.0	18.0	6.7	225	7.6
8.0	18.0	6.6	225	7.6
9.0	16.5	1.0	215	7.1
10.0	14.5	0.0	188	6.9
12.0	10.5	0.0	184	6.9

Site 2B, August 18, 1976--1400 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	24.5	9.6	212	8.6
1.0	24.5	9.6	212	8.5
2.0	24.5	9.6	212	8.5
5.0	23.0	6.3	220	7.6
6.0	22.0	4.0	220	7.2
7.0	21.0	3.4	200	7.0
8.0	20.5	3.1	190	6.0
9.0	18.5	2.1	182	6.9
10.0	14.5	0.0	180	7.0
15.0	8.0	0.0	165	7.0
17.0	7.5	0.0	170	7.1

Site 2B, September 29, 1976--1200 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	18.2	8.0	245	7.9
1.0	18.4	7.8	247	7.8
2.0	18.1	7.8	245	7.7
5.0	18.0	6.8	245	7.7
8.0	18.0	6.6	245	7.7
9.0	16.8	5.2	269	7.5
10.0	16.0	3.6	260	7.3
12.0	11.2	0.0	197	7.1
15.5	8.4	0.0	180	7.1

Site 3A, August 18, 1976--1130 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	24.5	8.6	178	8.1
1.0	23.5	8.2	170	7.9
2.0	23.0	8.1	170	7.8
5.0	23.0	7.8	172	7.8
6.0	22.5	2.9	180	7.1
7.0	21.5	2.3	178	6.9
8.0	20.0	4.7	125	6.8
9.0	18.0	0.5	140	6.7
10.0	16.0	1.8	155	6.9
15.0	8.0	2.0	142	6.9
17.5	6.5	1.3	148	7.1

Site 3A, September 29, 1976--1045 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	17.8	7.8	194	7.7
1.0	18.0	7.8	194	7.7
2.0	18.2	8.2	194	7.6
5.0	18.1	9.0	194	7.6
8.0	18.1	9.0	194	7.6
9.0	15.8	4.6	172	6.8
10.0	14.7	4.8	160	6.8
15.0	8.3	4.6	155	6.8
17.0	7.0	4.0	158	6.9

Site 4A, August 17, 1976--1600 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	25.5	8.6	152	8.6
1.0	25.5	8.6	152	8.3
2.0	25.0	8.7	152	8.3
5.0	24.5	8.2	151	8.7
6.0	23.0	7.9	156	7.8
7.0	22.0	1.6	152	6.9
9.0	17.5	2.6	140	7.0
10.0	14.5	4.2	135	7.0
15.0	8.5	6.0	120	7.1
20.0	6.5	5.8	128	7.2

Site 4A, September 28, 1976--1500 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	19.0	7.8	175	7.8
1.0	19.0	7.4	173	7.7
2.0	19.0	7.3	172	7.7
5.0	19.0	7.1	175	7.7
8.0	19.0	6.9	172	7.6
9.0	15.0	3.2	157	7.0
10.0	13.0	2.8	152	7.0
12.0	10.5	3.3	152	7.0
15.0	7.0	4.6	147	7.1
19.0	6.0	4.5	145	7.1

Site 4B
August 17, 1976--1700 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	25.0	9.1	152	8.4
1.0	25.5	8.7	152	8.3
5.0	24.5	8.8	152	8.3
6.0	24.0	8.7	148	8.2
7.0	21.0	2.7	148	7.0
8.0	19.5	3.4	145	6.9
10.0	15.5	4.9	138	7.0
14.0	10.0	4.6	128	7.0

Site 4B
September 28, 1976--1530 hrs

Depth (m)	Temperature (°C)	Dissolved oxygen (mg/L)	Specific conductance (µmhos at 25°C)	pH
0.5	19.0	8.0	172	7.8
1.0	19.0	8.2	172	7.7
2.0	19.0	8.3	172	7.7
5.0	19.0	9.0	172	7.7
8.0	18.5	6.7	170	7.4
9.0	14.0	3.0	149	7.0
10.0	12.5	2.8	150	6.9
12.0	10.5	2.0	148	6.8
13.0	8.5	2.3	148	6.8

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