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PHYSICAL AND CHEMICAL PARAMETERS OF DEEP LAKE, VESTFOLD HILLS, ANTARCTICA

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PHYSICAL AND CHEMICAL PARAMETERS OF DEEP LAKE, VESTFOLD HILLS, ANTARCTICA

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ABSTRACT

Physical and chemical data collected between October 1973 and January 1976, during an ecological study of Deep Lake, are collated and summarized.

The hypersaline lake (Total Dissolved Salts (TDS) = 270 g/l) remained ice free throughout the study period and, with the exception of temperature, provided a very stable physical and chemical environment. Concentrations of major ions are listed. Slight changes in chloride concentrations occurred near the surface and below twenty-five metres but they were the result of physical events and probably of no biological significance.

Concentrations of inorganic nutrients were similar to, and organic nutrients much higher than, those in sea water. The latter observation and the absence of variation in concentration with depth and time reflect the lack of biological activity in the lake.

Plate 1. A view of Deep Lake from the north-east showing the terrace that rims the lake and Deep Lake Tarn in the foreground.

1. INTRODUCTION

Deep Lake (68° 33.6'S, 78° 11.6'E) is one of several extremely saline lakes in the Vestfold Hills, Antarctica (Figure 1 and Plate 1). These lakes are remnants of an arm of the sea which was isolated by isostatic uplift of the area after retreat of the edge of the polar ice cap, probably during the last post-glacial optimum about 6,000 years ago. Evaporation in the dry and windy environment has resulted in concentration of salts from an original 35 g/l to between 210 and 280 g/l.

McLeod (1964) described the setting and the ionic composition of the lakes and suggested their origin. The general biology of the Vestfold Hills has been discussed by Johnstone et al. (1973). This report summarizes physical and chemical data collected from Deep Lake between August 1973 and January 1976 by biologists wintering at Davis Station, and includes some data previously published by Kerry et al. (1977).

2. METHODS

2.1 Sampling

Unless otherwise stated, water samples were collected from Station A of Figure 4 in a polyvinyl chloride Van Dorn water bottle which contained a mercury glass thermometer. The thermometer was viewed through a window in the side of the water bottle. After collection, most samples were placed in polyethylene bottles which were tightly sealed and returned to Davis Station. Samples for nutrient analysis were stored at about - 15°C. Samples for major ion and trace metal measurement were kept unrefrigerated and returned to Australia; those for trace metal analysis were stored in acid-washed bottles.

Sediment samples were collected with a Petersen grab or a gravity corer and measurements carried out at Davis.

2.2 Physical Methods

Morphometric parameters were estimated from aerial photographs of Deep Lake and its catchment and from direct measurement of the bathymetry of the lake. Volume was calculated from depth contours.

Temperatures of all water samples were measured with the thermometer in the water bottle. In addition, more comprehensive temperature profiles were obtained with the water bottle and on several occasions with a thermistor.

Light penetration was measured with a Kahl Scientific Instrument Corporation submarine photometer fitted with Schott RG1, VG9 and BG12 filters. A deck cell was used to measure changes in the intensity of the incident light. Transmission at various depths was calculated by the method described in Vollenweider (1974).

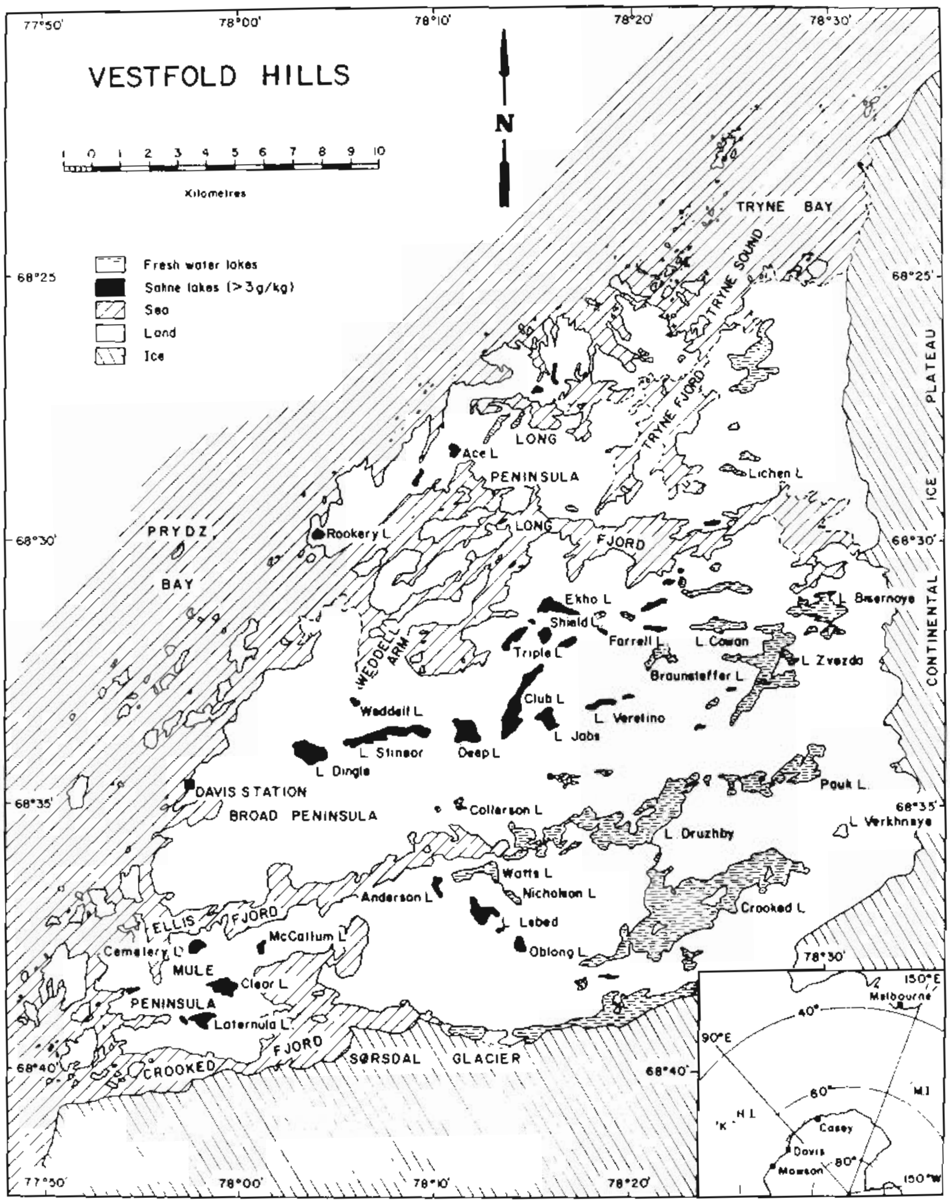

Figure 1. A map of the Vestfold Hills. The hypersaline lakes include Lake Dingle, Lake Stinear, Deep Lake and Club Lake.

2.3 Chemical Methods

2.3.1 Dissolved Oxygen

Dissolved oxygen (DO) concentrations were measured by the Winkler method as described by Major et al. (1972) prior to February 1974 and by the method of Strickland and Parsons (1972) thereafter. Samples were collected in glass Biological Oxygen Demand bottles and fixed immediately with solid manganous sulphate and alkaline iodide solution. They were then returned to the laboratory where the manganous hydroxide precipitate was dissolved. This often proved to be difficult but could be accomplished by the addition of extra acid.

2.3.2 Total Dissolved Solids

Total dissolved solids (TDS) were determined by evaporating 100 ml of lake water to dryness at 104°C. Because of the high salt content it was necessary to dry the samples over a long period. Samples from 13 May 1975 were dried for twenty-four days and samples from 6 June 1975 for 108 days.

2.3.3 Major Ions

The concentrations of major ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-}, HCO_3^-) were determined by a variety of methods. Samples collected in 1973 were returned to Australia where sodium and potassium concentrations were measured by flame photometry and magnesium and calcium by atomic absorption spectroscopy. The same cations were all determined by atomic spectroscopy at Davis in 1974 after dilution of 1:5,000 with deionised water. Chloride concentrations were measured titrimetrically by the low precision method of Strickland and Parsons (1972) after a 1:10 dilution and therefore include other halides. A gravimetric method, derived from Vogel (1961) was used to estimate sulphate concentrations. Twenty millilitres of lake water, was acidified with 0.2 ml of concentrated HCl and made up to 100 ml with deionised water. Saturated picric acid solution (ten millilitres) and five per cent $BaCl_2$ solution (five millilitres) were then added. The solution was gently boiled for ten minutes and the resulting precipitate of $BaSO_4$ collected on a millipore filter. After washing with cold, deionised water, the filter with precipitate was dried and weighed. Bicarbonate (HCO_3^-) was calculated from the total alkalinity which was determined by the method of Golterman and Clymo (1959).

2.3.4 Nutrients

The concentration of nutrients (PO_4-P, Total P, NO_3-N, NO_2-N, Total N, SiO_2-Si, Carbohydrate) were also determined by a number of methods. The single solution method of Major et al. (1972) was used throughout 1974 and 1975 in the measurement of reactive phosphate phosphorus (PO_4-P). Prior to 25 June 1975 isobutanol extraction, as described by Strickland and Parsons (1972), was necessary to intensify the colour of the lake water plus reagents. After 25 June, 50 per cent dilution of the sample and an incubation time of two hours resulted in more intense and more rapid colour development and consistent absorption values.

Consequently, isobutanol extraction was no longer required. The effect of dilution on the reaction is shown in Figure 2.

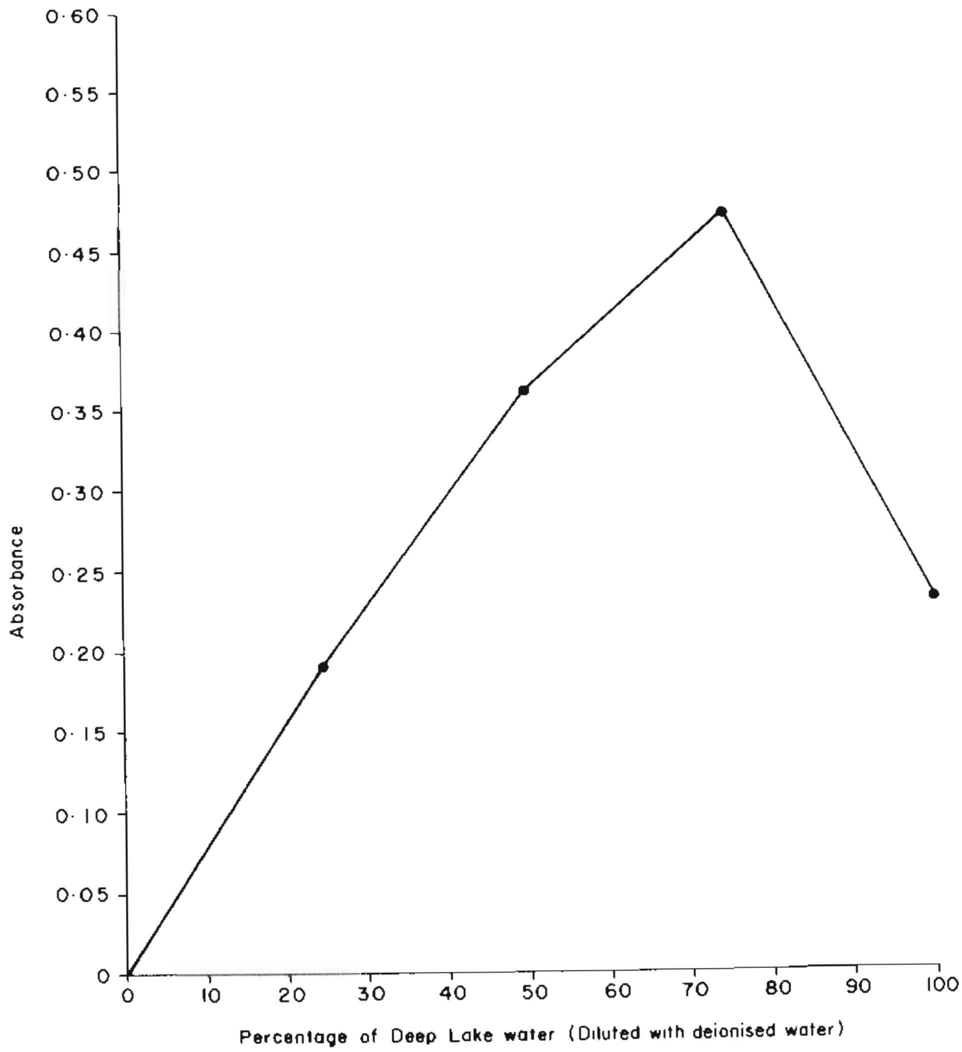

Figure 2. Reactive phosphate analysis. The effect of dilution on absorbance of lake water two hours after addition of the mixed reagent (as measured on a Beckman DB-GT spectrophotometer with 4 cm cells).

Total phosphorus in the lake water was measured as reactive phosphate phosphorus after being oxidized by persulphate in an autoclave (Major et al., 1972). Sediment samples (twenty grams wet weight) were suspended in 100 ml of deionised water and treated in the same way.

The cadmium reduction method described by Strickland and Parsons (1972) was used to determine reactive nitrate nitrogen (NO_3-N) levels. The high salt concentrations may have affected this analysis as values obtained using the calibration procedure of Strickland and Parsons and a standard curve were about fourteen per cent lower than those obtained by the method of standard addition. This was not allowed for in the results, so the values for NO_3-N (Table 9 and Appendix F) should be approximately fourteen per cent higher.

Reactive nitrite nitrogen (NO_2-N) was measured by the method of Strickland and Parsons (1972) and appeared to be unaffected by the high salt concentrations. The same method was used to measure ammonia (plus amino acids) after it was oxidized to nitrite by hypochlorite in an alkaline medium.

Total nitrogen in two grams (wet weight) of sediment was converted to ammonia by Kjelkahl digestion. The ammonia (plus amino acids) was then measured by the method of Strickland and Parsons (1972). An attempt at Davis Station to determine the total nitrogen content of lake water was unsuccessful as the high salt content interfered with the digestion process. Values for total nitrogen presented in Chapter 4.6 were obtained from samples returned to Australia and analysed by a commercial laboratory.

Prior to February 1974 reactive silicate silicon (SiO_2-Si) concentrations were estimated by the method of Golterman and Clymo (1969); from February 1974 the method of Strickland and Parsons (1972) was followed. In both cases a 1:10 dilution of lake water with deionised water was employed to overcome salt inhibition of the reaction.

Carbohydrate, in both sediment and water, was measured by the phenol-sulphuric acid method of Liu et al. (1973) with soluble starch as the standard. About twenty milligrams (wet weight) of sediment or one millilitre of water was used in each analysis.

2.3.5 Electrochemical

The Redox Potentials (Eh) and Hydrogen ion concentrations (pH) of the water and sediment samples were measured in the laboratory at Davis with a Radiometer PHM26 meter.

3. PHYSICAL PROPERTIES

3.1 Morphometric Parameters

Apart from area, mean depth and volume, all morphometric data presented in Table 1 are identical to those published by Kerry et al. (1977). The small differences that do occur are due to the availability of more information for this report and the use of depth contours rather than a geometric formula to calculate volume.

Deep Lake and its catchment (Figure 3) form a steep-sided basin with two shallower valleys entering from the north-west and south-west. As a consequence, the catchment area is relatively small and only slightly larger than the original lake. The surface of the lake is approximately 50.4 m below present sea level and about 54.4 m below a marine terrace which rings the entire lake basin (Kerry et al., 1977). This marine terrace represents sea level at the time of isolation of the lake from the sea.

The only discontinuity in the basin is a shallow area towards the centre of the lake near Station C (Figure 4). Sediment from this area has a higher organic content than other areas of the lake (see Chapter 5) and probably benefits from inflow from Deep Lake Tarn.

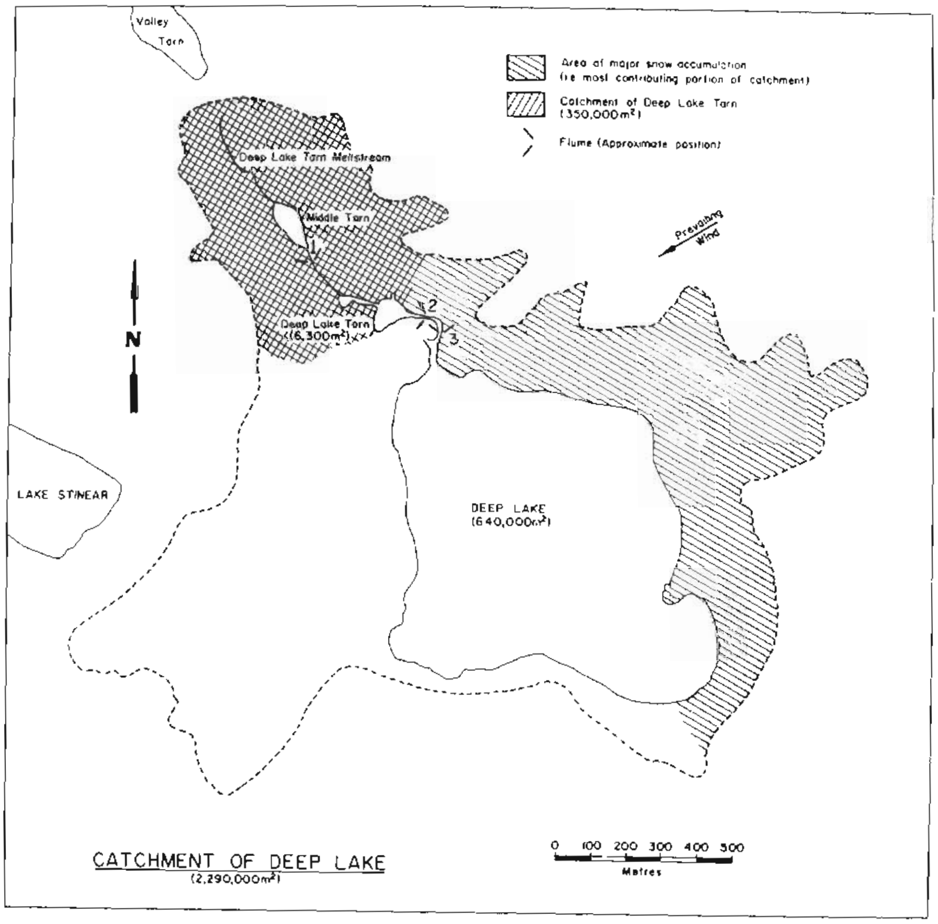

Figure 3. Catchment of Deep Lake and Deep Lake Tarn showing areas of snow accumulation.

Area	5.83×10^5 m^2
Max. length	1.19×10^3 m
Max breadth	9.20×10^2 m
Max depth	36 m
Volume	10.9×10^6 m^3
Mean depth	18.7 m
Catchment area	2.29×10^6 m^2
Area of lake at time of cut-off from the sea	1.71×10^6 m^2

Table 1. Morphometric parameters of Deep Lake.

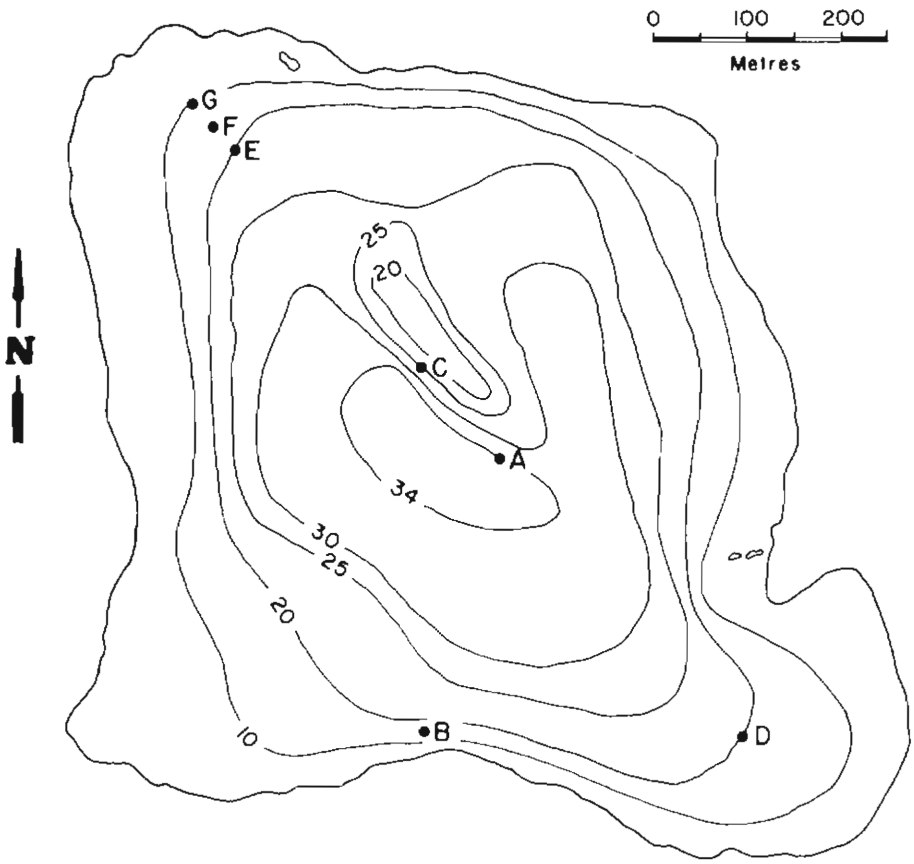

Figure 4. Sampling sites on a bathymetric map of Deep Lake (depths in metres).

3.2 Temperature

The lake was thermally stratified for most of the study period but did mix completely during winter of 1975 when the water column was homothermal (Figure 6 and Appendix A). A thermocline was established in spring each year as solar radiation increased and the water in the epilimnion warmed rapidly. Heat was lost just as rapidly in autumn and winter as winds became stronger, and the air temperature lower. This caused the downward movement of the thermocline.

The surface waters varied in temperature from -18.3°C in August 1973 to a maximum of +11.5°C in January 1974. The wide range of temperatures and the rapid gain and loss of heat near the surface, under the influence of climatic changes, was probably due to the high salinity of the water. Not only did this prevent the lake from freezing and thus gaining some degree of insulation but it also lowered the specific heat of the water.

The temperature of water below twenty metres was constant throughout most of each year but did change rapidly during winter mixing. The minimum recorded was -17.2°C in September 1975 and the maximum was -8.5°C in April 1975.

A slight increase in temperature was observed near the bottom of the lake in 1973, 1974 and early 1975 but was not recorded after the prolonged holomixis of 1975.

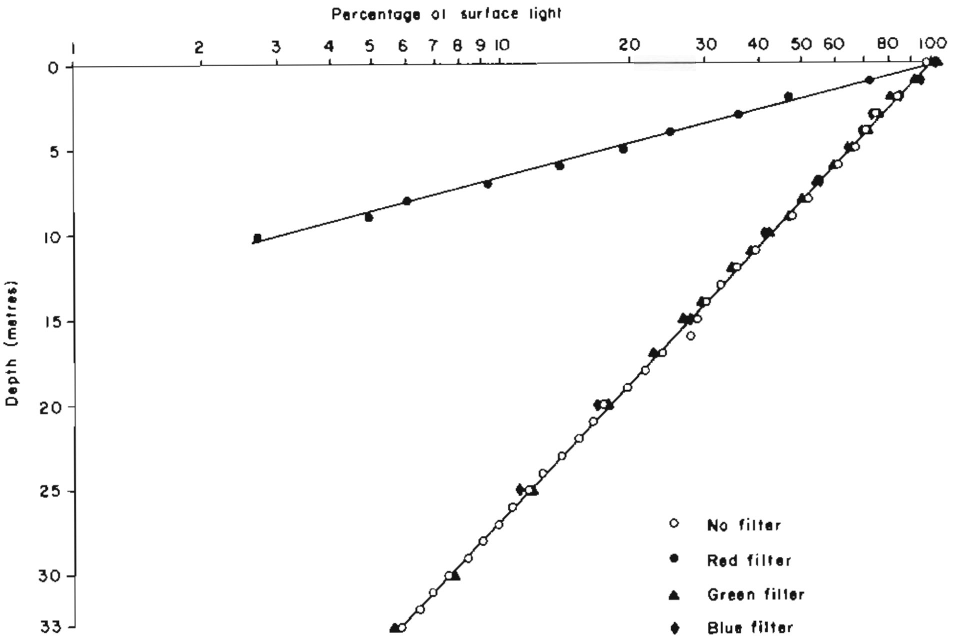

Figure 5. Penetration of light in Deep Lake on 19 May 1975.

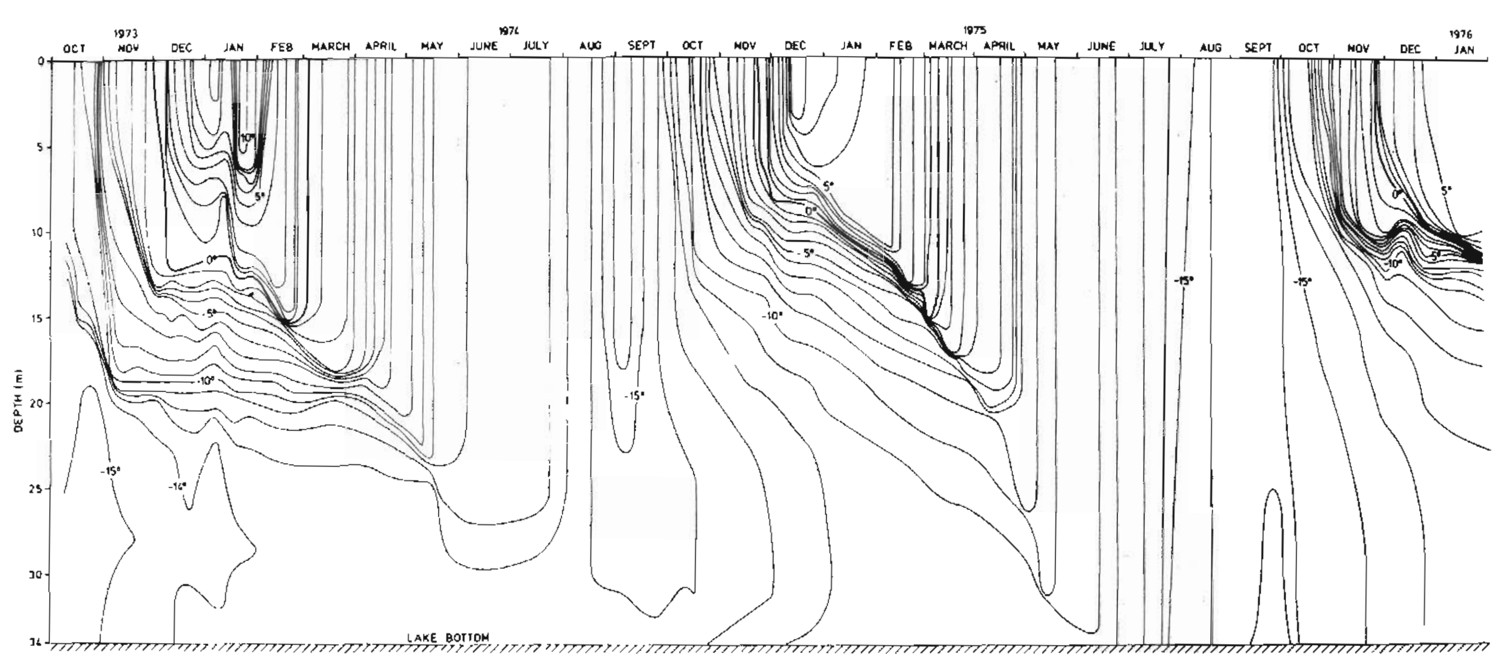

Figure 6. Deep Lake isotherms, October 1973 to January 1976.

3.3 Light

Because very little organic matter or colloidal material flows into Deep Lake and biological activity is extremely low (Campbell, 1978 and R. Williams, pers. comm.), the water is very clear. At Station A (Figure 4), light always penetrated to the bottom of the lake where a mean of 3.8% of unfiltered surface light was recorded (Figure 5 and Appendix B). Light measured through blue and green filters behaved similarly and was absorbed logarithmically through the water column. Red light was absorbed or scattered rapidly and was not detected below fifteen metres.

4. CHEMICAL PROPERTIES

4.1 Hydrogen Ion Concentration

The Hydrogen ion concentration (pH) of Deep Lake water was found to vary little with depth or time (Table 2). Those variations recorded were probably due to experimental error. The mean value of 7.42 is similar to that given by Copeland (1967) for seawater concentrated to the same extent as water in Deep Lake.

Total alkalinity (TA) was measured on several occasions and those results have been presented in Appendix D as bicarbonate (HCO_3^-). A mean TA value of 4.60 meq/l was obtained. This indicates that water in Deep Lake has a greater buffering capacity than sea water which has a similar pH but a total alkalinity of only 2.53 meq/l (Dyrssen, 1969).

4.2 Redox Potential

Redox Potentials (Eh) of the water column were large and positive (mean = +462 mv) on the three dates they were measured and did not show any regular variations with depth (Table 3).

Depth (m)	11 Aug. 1974	2 Mar. 1975	18 Mar. 1975
1	+440	+475	+463
5	-	+475	+468
10	+428	+473	+465
15	-	+472	+468
20	+432	+474	+466
25	-	+473	+470
30	+430	+474	+466
33	-	+467	+465

Table 3. Oxidation-reduction potentials of Deep Lake water (mv).

Depth (m)	1973		1974									1975	
	9 Aug	18 Oct	21 Jan	29 Jan	18 Feb	21 Mar	3 Apr	26 Apr	21 May	14 Jul	11 Aug	2 Mar	18 Mar
Surf	7.50	7.40	-	-	-	-	-	-	-	-	-	-	-
1	-	-	7.40	7.40	-	-	7.40	7.38	7.58	7.38	7.43	7.49	7.44
5	-	-	7.40	-	-	7.34	-	-	-	-	-	7.50	7.39
10	-	7.45	-	-	7.48	-	7.39	7.26	7.35	7.36	7.40	7.49	7.45
15	-	-	-	-	-	-	-	-	-	-	-	7.49	7.40
20	-	-	-	-	7.51	-	-	-	-	-	7.42	7.49	7.49
25	-	-	-	-	-	7.41	7.38	7.28	7.32	7.36	7.40	7.50	7.44
30	-	-	-	-	-	-	-	-	-	-	-	7.49	7.49
33	-	-	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	7.40	-	-	-	-	-	-	-	-	-

Table 2. pH of Deep Lake water.

Even in March 1975 after five months of stratification, there was no sign of decreased Eh at the bottom of the lake.

The Eh in the sediments did decrease slightly with depth but was still +274 mv at twenty-two centimetres, the greatest distance measured into a core (Table 4).

4.3 Dissolved Oxygen

Dissolved oxygen concentrations in the water of Deep Lake are close to saturation values found in other highly saline waters (Bayly and Williams 1973, Copeland 1967).

During holomixis, when temperatures were uniform throughout the lake, dissolved oxygen concentrations were also constant (Figure 7 and Appendix C). However, when the lake became thermally stratified, an inverse relationship between the two was established. This is characteristic of an oxygen distribution imparted by purely physical events (Hutchinson 1957). The effect of temperature on dissolved oxygen concentrations in the highly saline waters of Deep Lake can be seen in Figure 7 which is a graphical representation of all data

18 March 1975		25 March 1975			
		CORE I		CORE II	
Depth (cm)	Eh (mv)	Depth (cm)	Eh (mv)	Depth (cm)	Eh (mv)
0-2	+542	0-2	+465	0-2	+473
2-4	+512	2-4	+454	2-4	+433
4-6	+514	4-6	+413	4-6	+404
6-8	+229	6-8	+402	6-8	+392
8-10	+182	8-10	+384	8-10	+374
10-12	+169	10-12	+349	10-12	+352
				12-14	+343
				14-16	+316
				16-18	+323
				18-20	+274
				20-22	+274

Table 4. Oxidation-reduction potentials of Deep Lake sediment. (All cores were collected from a depth of 25 m near the centre of the lake at Station C).

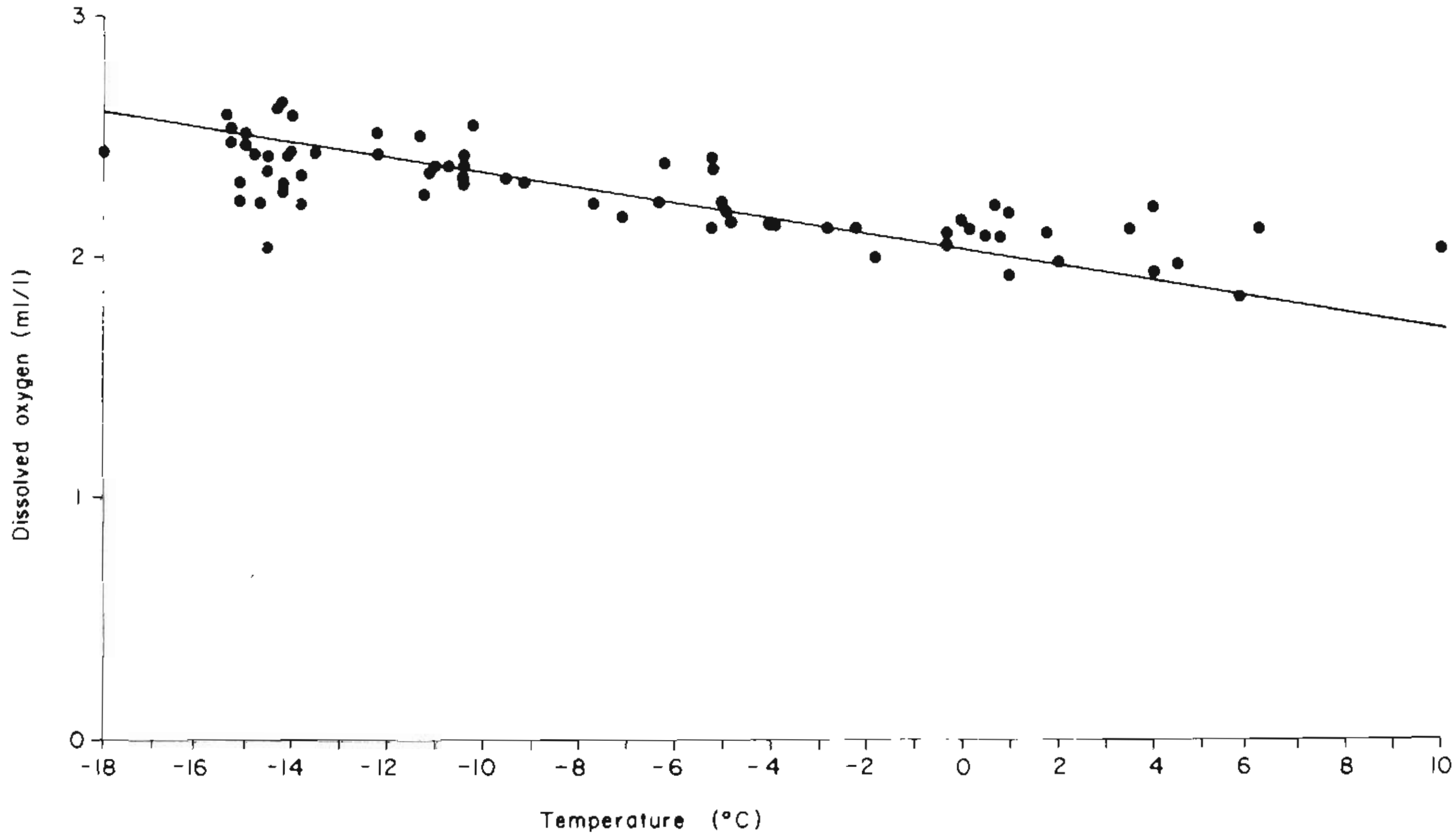

Figure 7. *Graphical representation of all data in Appendix C. The linear relationship ($x = -31.56\ y + 64.00$) was calculated by the method of least squares.*

contained in Appendix C. The linear relationship was calculated by the method of least squares (American Public Health Association et al., 1971).

In 1973 and early 1974, but not in the latter half of 1975, oxygen concentrations near the bottom of the lake were less than in the water above. Considering the extremely low level of biological activity in the lake, it seems likely that this apparent depletion of oxygen in the bottom water was the result of the slightly higher salinity and temperature of the unmixed bottom layer prior to holomixis in 1975, rather than the result of any biological process.

4.4 Total Dissolved Solids

Both series of measurements of Total Dissolved Solids (TDS) were reasonably constant throughout the water column with a slight increase at the bottom (Table 5).

Haldane (1959) found similar values when he dried Deep Lake water at 120°C, but found considerably lower values (mean 270.4 g/l) after drying at 180°C. The latter values were always close to the total weight of the individual ions and are therefore more useful in discussing the salinity of the lake.

4.5 Major Ions

The concentrations of major ions (Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Cl^{-}, HCO_3^{-}, SO_4^{2-}, Br^{-}) measured during 1974 and 1975 (Table 6 and Appendix D) were similar to those reported by McLeod (1964) and Kerry et al. (1977). Chloride was measured most frequently and was found to vary systematically (Figure 8 and Appendix E).

Depth (m)	13 May 1975 *	6 June 1975 **
1	284.9	281.8
5	284.9	279.8
15	286.7	281.4
20	286.6	282.1
25	285.8	282.6
30	285.0	281.7
33	289.5	285.2

* Dried for 24 days ** Dried for 108 days

Table 5. Total dissolved solids (g/l) in Deep Lake water dried at 104°C.

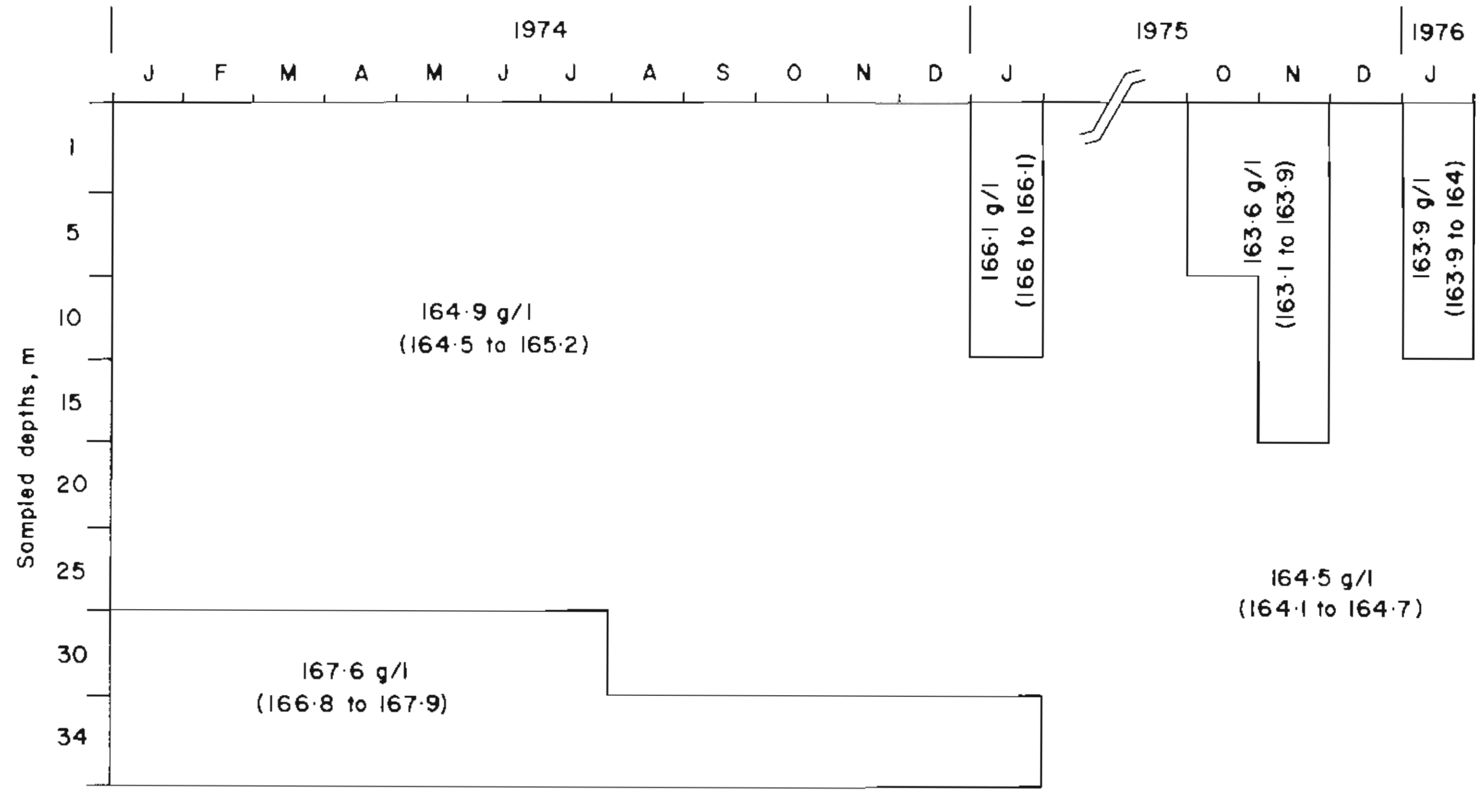

Figure 8. Chloride concentrations in Deep Lake.

	Sea Water *	10 x Sea Water	Deep Lake **
Na^+	11.07	110.7	67.9
K^+	0.41	4.1	4.24
Mg^{2+}	1.33	13.3	12.5
Ca^{2+}	0.42	4.2	2.40
Cl^-	19.90	199.0	165.0
HCO_3^-	-	-	0.281
SO_4^{2-}	2.78	27.8	2.82
Br^-	0.069	0.69	0.68
B	0.0047	0.047	0.0046

* Average values from Smith (1974) ** Mean concentrations

Table 6, Major Ion concentrations (g/l),

Slight changes occurred in the top ten metres in response to evaporation, precipitation and melt water inflow. The highest surface concentration recorded was 166.1 g/l in January 1975, and the lowest was 163.0 g/l in October 1975 after heavy snowfall.

During 1974 and January 1975 the mean chloride concentration near the bottom of the lake was 167.6 g/l, 2.7 g/l higher than in the remainder of the water column. This bottom layer was not destroyed during the winter of 1974, and although it was eroded (Figure 8) it remained until measurements ceased in January 1975. When chloride measurements resumed in October 1975, the bottom layer was absent, presumably destroyed during the winter holomixis of 1975.

As previously discussed by McLeod (1964) and Kerry et al. (1977), the Na^+ : Ca^{2+} and Cl^- : SO_4^{2-} ratios indicate that the lake is of marine origin. That conclusion is supported by geomorphological evidence and the presence of remains of marine organisms in the terraces around the lake.

The original sea water has evaporated under cold conditions until now the TDS is 270 g/l. Concentration of the water has resulted in changes in ionic composition as various salts have crystallized out of solution. A concentration factor for Deep Lake can be calculated by comparing its Br^- and K^+ levels with those in sea water, because these ions are deposited only in the last stages of both frigid concentration (Table 7) and evaporation (Table 8) of sea water. On this basis, a concentration factor of ten was calculated and that has been used in Table 6 to obtain a theoretical composition for Deep Lake. This differs only slightly from the concentration factor of eleven given by McLeod (1964).

Salt	Temperature at which precipitation commenced
$Na_2SO_4.10H_2O$	$- 8.2^{o}C$
$NaCl.2H_2O$	$- 22.9^{o}C$
$KCl,MgCl_2$	$- 36.0^{o}C$
$CaCl_2.6H_2O$	$- 54.0^{o}C$

Table 7. Precipitation of salts from sea water by frigid concentration Nelson & Thompson, (1954). (When the temperature of the brine was allowed to rise again, $CaCO_3$ was precipitated).

Salts	Salinity at which separation began
$Fe_2O_3,CaCO_3$	$70^{o}/oo$
BO_3^{3-}	$120^{o}/oo$
$CaSO_4$	$150^{o}/oo$
$NaCl,MgSO_4,MgCl_2$	$290^{o}/oo$
$NaBr,KCl$	$> 300^{o}/oo$

Table 8. Precipitation of salts during concentration of sea water by evaporation (Copeland, 1967).

Assuming the original water had an ionic composition similar to that of present day sea water, it appears that considerable proportions of sodium, calcium, chloride and sulphate have been lost from solution (Table 6). Large mirabilite ($Na_2SO_4.10H_2O$) deposits around Deep Lake (Plate 2) and the presence of bands of tne mineral in recent sediments (Plate 3) provide a ready explanation of the loss of sodium and sulphate ions. Present deposition is confined to bottom depths of below thirty-two metres. Chloride ions have most probably been deposited as halite (NaCl) or hydrohalite ($NaCl.2H_2O$), although no evidence for this has as yet been found. Calcium may have been lost as gypsum ($CaSO_4.2H_2O$) or calcium carbonate or even antarcticite ($CaCl_2.6H_2O$) but again there is no evidence available.

4.6 Nutrients

The nutrient concentrations were remarkably constant throughout the study period, and there was very little variation with depth (Table 9 and Appendix F). Inorganic nutrients were present in concentrations within the ranges given for sea water, while organic nutrients exceeded the sea water concentrations given in Sverdrup et al. (1942). Total-P concentrations (mean = 271.1 µg/l) were much higher than the 40 µg/l found in uncontaminated lake surface waters (Bayly and Williams, 1973) and the Total Organic Carbon concentrations of 50 ppm at one

	Mean	Standard Deviation	Number of Measurements
Total - P (ug/l)	271.1	20.5	70
Reactive PO_4-P (µg/l)	56.7	3.1	98
Reactive NO_3 - N (µg/l)	72.1	3.1	176
Reactive NO_2 - N (µg/l)	3.05	0.38	199
Ammonia (Plus Amino Acids)	B.L.D.*	-	-
Reactive SiO_2- Si (mg/l)	3.06	0.55	44
Carbohydrate (mg/l)	23.7	1.9	28

* Analysis for ammonia was attempted on one occasion in January 1975.

Table 9. Concentrations of major nutrients in Deep Lake.

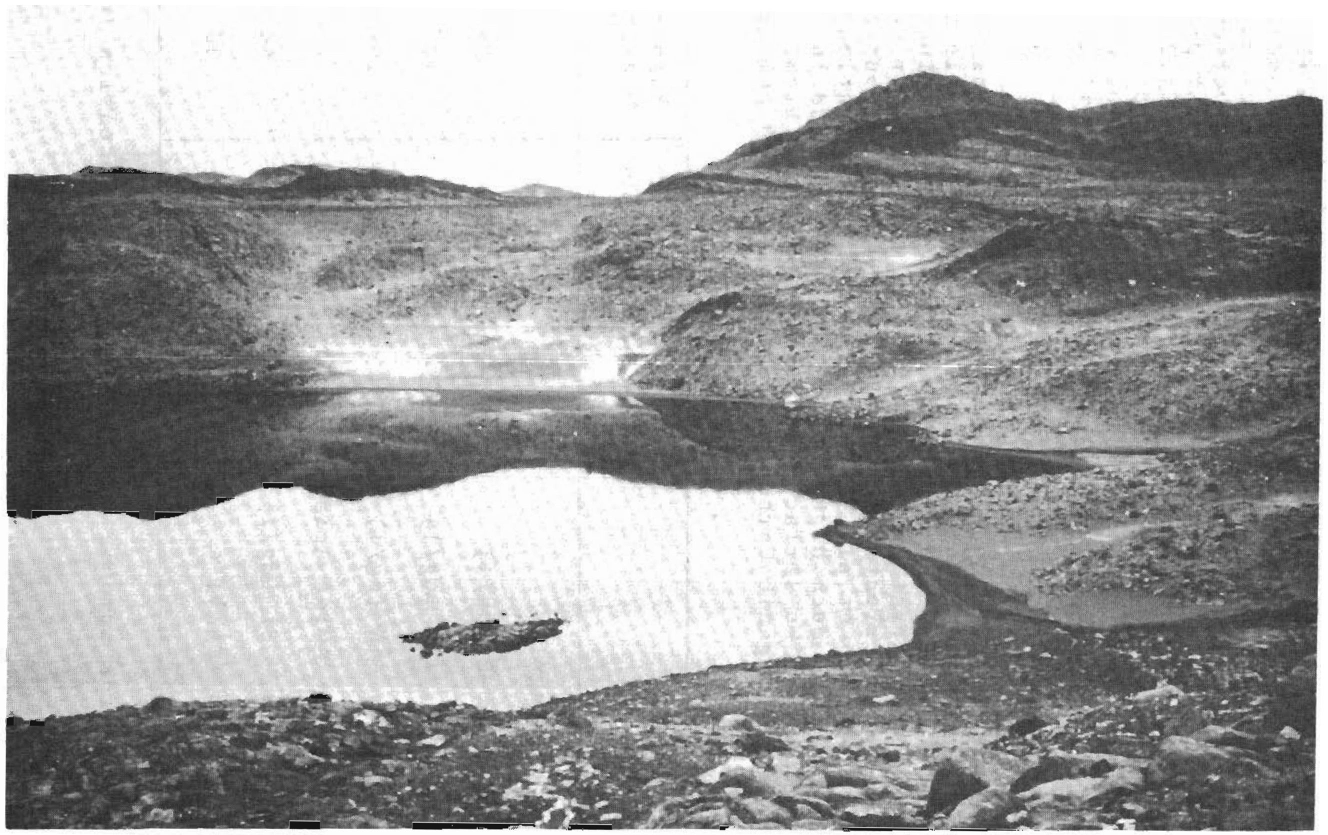

Plate 2. Mirabilite deposit on the shore of Deep Lake.

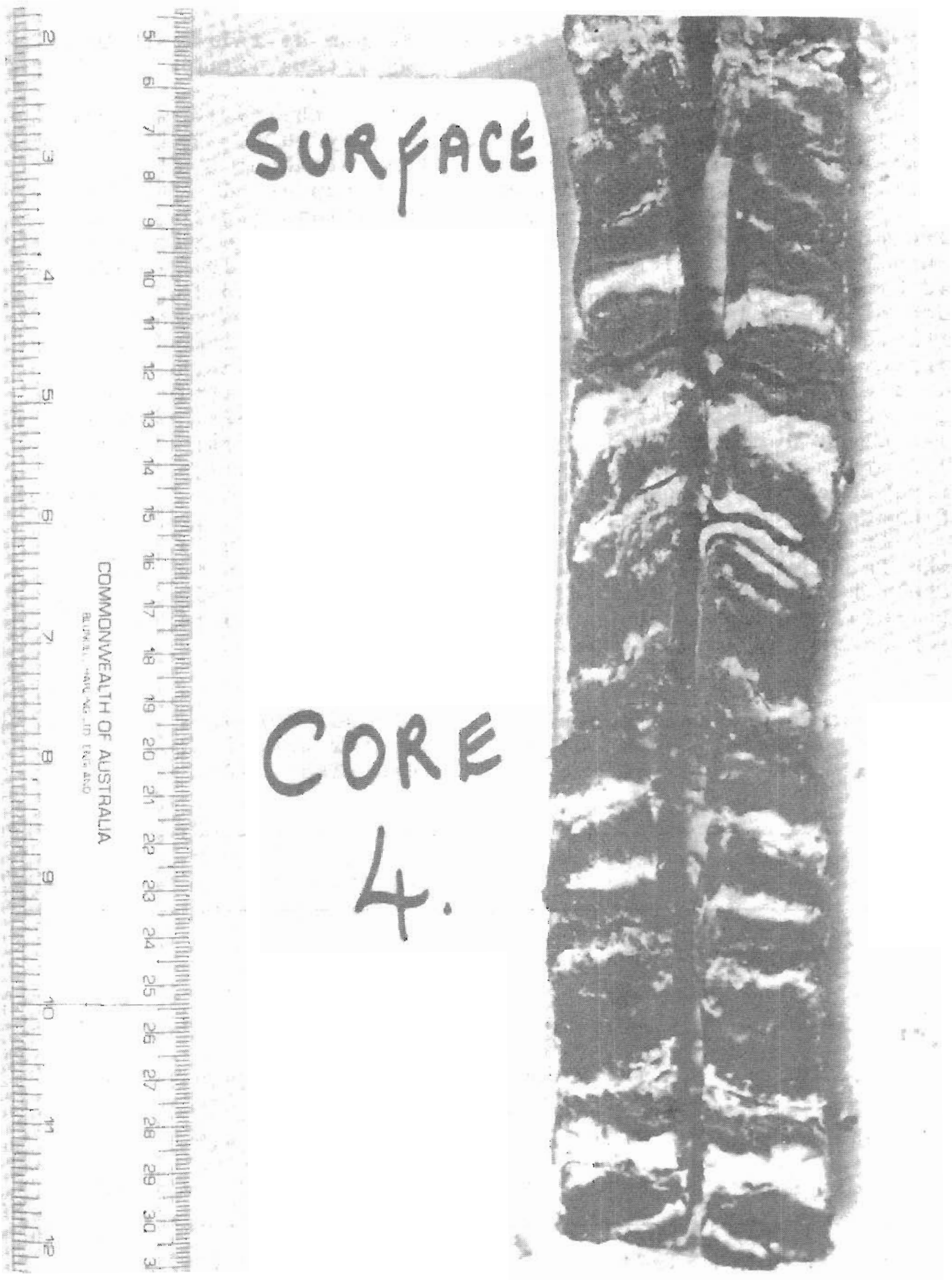

Plate 3. A core from Deep Lake. White bands of mirabilite are separated by layers of fine sand.

metre, 49 ppm at fifteen metres and 46 ppm at thirty-three metres were about the same as in swamp waters (Stumm and Morgan, 1970). Total nitrogen values of 7.9 mg/l at fifteen metres, 6.9 mg/l at twenty metres and 7.1 mg/l at thirty-three metres were found in samples collected on 16 July 1975. These are far greater than in sea waters where values of about 0.14 mg/l of total nitrogen have been reported (Sverdrup et al., 1942).

High Total Organic Carbon concentrations (up to 50 mgC/l) have previously been reported from Lake Bonney, a saline lake in South Victoria Land, Antarctica (Parker et al., 1974; Matsumoto and Hanya, 1977). Parker et al. (1974) suggested that, although much of the organic matter in Lake Bonney was dissolved extracellular material which had been there for some time, an appreciable fraction was produced and recycled annually. From the biological data available, it appears that little cycling can occur in Deep Lake. In 1974 R. Williams (pers. comm.) found that algal numbers remained low throughout the year while in 1975 primary production was unmeasurable (Campbell, 1978). Microbiological sampling in 1976-77 summer revealed low numbers of bacteria throughout the water column (R. Hand, pers. comm.).

It is therefore proposed that organic carbon from Deep Lake Tarn and extremely low primary production in the lake itself have slowly accumulated in the absence of significant microbial decomposition. Both total nitrogen and total phosphorus may have accumulated in the same way.

4.7 Trace Metals

Cadmium and lead concentrations do not change significantly through the water column of Deep Lake; for copper, the marked decrease with depth remains unexplained (Table 10).

Deep Lake 1 Jan. 1977	Cadmium (μg/l)	Lead (μg/l)	Copper (μg/l)
1 m	6.3±2.9	3.7±0.6	21.0±2.0
15 m	4.5±1.1	5.2±2.1	13.7±1.6
33 m	4.3±0.8	4.5±1.7	9.1±1.9
* Sea Water	0.113	0.05	2,1.2 and 0.7
**Dead Sea	8-10	120-300	300-500

* From Smith (1974) ** From Nissenbaum (1977)

Table 10. Concentrations of trace metals.

The toxic effect of trace metals has been considered as an explanation for the lack of biological activity in Deep Lake and from Table 10 it is obvious that the concentrations in Deep Lake are much higher than in sea water. However in the Dead Sea, where there is considerable biological activity (Kaplan and Friedmann, 1970), those concentrations are higher still.

5. BOTTOM SEDIMENT

Organic components in surface samples of sediment were measured in 1975 and the results appear in Table 11. Generally samples from Station C, which probably receives particulate matter from Deep Lake Tarn, contained most organic matter while sediment from Station F had the lowest organic component. The area around the inflow from Deep Lake Tarn was obviously rich in organic matter but no measurements were made there.

The sediment from around the edge of the lake tended to be mainly coarse-grained sand but in the centre of the lake, at depths greater than thirty-two metres, the bottom consisted mainly of mirabilite ($Na_2SO_4.10H_2O$) and fine-grained sand. Sediment cores characteristically consisted of layers of dark sand interspersed with thin layers of mirabilite (Plate 3).

Station	18 March 1975		25 March 1975		9 April 1975	
	Total N	Carbo-hydrates	Total N	Carbo-hydrates	Total N	Carbo-hydrates
A	0.170	2.50	0.169	2.49	0.066	2.72
C	0.242	4.39	0.274	3.70	0.214	4.29
E	0.148	-	0.070	1.19	0.377	3.04
F	0.077	2.22	0.044	1.09	0.031	2.23
G	-	-	0.086	1.99	0.108	2.51

Total N (mg. Nitrogen/g.Dry Weight).
Carbohydrate (mg.Starch/g.Dry Weight).

Table 11. Concentrations of organic components in surface sediment samples from Deep Lake.

6. DEEP LAKE TARN

The Deep Lake catchment area is small, but it does sustain one considerable stream which flows through Deep Lake Tarn (Figure 3) for a short period each summer. Sampling sites are indicated on Figure 9, and incidental observations and measurements on water flowing into and out of the tarn prior to 1977 have been assembled in Tables 12, 13 and 14.

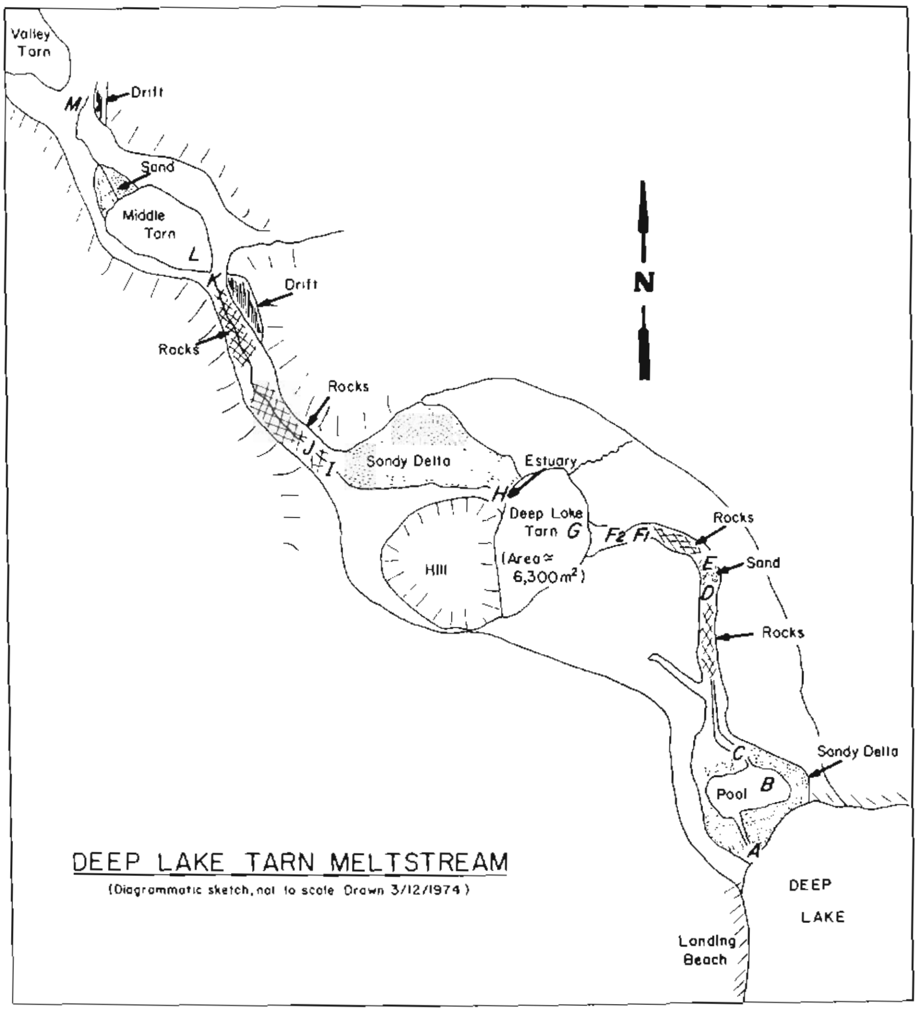

Figure 9. Deep Lake Tarn and meltstream with sampling sites.

Flow	1973-74	1974-75	1975-76
Began	10 Dec. 1973	28 Nov. 1974	15 Dec. 1975
Ended	4 Feb. 1974	13 Jan. 1975	after 13 Jan. 1976
Days of Substantial Flow	56	46	>29

Table 12. Flow of water from Deep Lake Tarn to Deep Lake.

Date	Sampling Site	Na^+ (mg/l)	K^+ (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)
21 Jan. 1974	J	60.2	2.5	4.6	7.5
	H	66.5	2.6	5.2	8.5
	G	74.4	3.0	5.8	10.0
	D	129.3	6.9	15.3	19.6
18 Feb. 1974	G	145.3	5.8	19.6	21.8

Table 13. Major ions in Deep Lake Tarn and meltstream.

Date	Sampling Site	PO_4-P (µg/l)	NO_3-N (µg/l)	NO_2-N (µg/l)	SiO_2-Si (mg/l)
18 Feb. 1974	G	2.8	14.0	<1.0	2.14
10 Dec. 1975	G	6.2	1.0	*B.L.D.	-
23 Dec. 1975	B	*B.L.D.	160.0	*B.L.D.	-
13 Jan. 1976	G	*B.L.D.	22.5	*B.L.D.	-
	F_2	*B.L.D.	10.1	*B.L.D.	-
	F_1	*B.L.D.	39.6	*B.L.D.	-
	D	*B.L.D.	34.6	*B.L.D.	-
	C	*B.L.D.	37.1	*B.L.D.	-

* Below limit of detection.

Table 14. Nutrient levels in Deep Lake Tarn and meltstream.

Commencement and duration of input of water into Deep Lake during summer were governed by the weather conditions of the preceding year. In 1973 mean air temperatures were average for the Vestfold Hills and snow fell on 170 days. This resulted in flow commencing on 10 December 1973 and lasting for 56 days (Table 12). The following year was warmer than average and snow fell on only 100 days. Consequently water began flowing earlier and continued for only 46 days.

The water carried with it small quantities of major ions and nutrients (Tables 13 and 14). From Table 13 it appears that the water gradually picked up ions as it approached Deep Lake but was still essentially fresh water as it entered the lake. The concentration of ions in the tarn was low while water was flowing through it, but increased slightly when flow ceased. Nutrient levels were generally low although soon after flow began in 1975, high levels of NO_3-N (160 µg/l compared with 72.1 µg/l in Deep Lake) were measured. Subsequent values were much lower suggesting that the early flow flushed out nutrients which had accumulated prior to summer, probably as a result of biological oxidation of organic matter.

In 1977 a flume (Figure 3) was established in the stream between Deep Lake Tarn and Deep Lake to gauge the quantity of water passing between the two. As yet no data from this are available.

7. GENERAL DISCUSSION

Deep Lake was chemically a very uniform body of water during the study period, although there were slight changes in chloride concentration near the surface in response to evaporation, melt water inflow and snowfall. The only other anomaly in the water column was a layer which had a higher than expected chloride concentration, temperature and TDS and lower DO at depths below twenty-five metres. This bottom layer was partially destroyed during August 1974 when the lake mixed to a depth of about thirty metres. An abnormally calm September prevented further wind-driven mixing and so the bottom layer survived until holomixis in the winter of 1975 (H.R. Burton, pers. comm). The bottom layer, with slightly different chemical and physical properties, was possibly a remnant of water present in the lake after the previous complete mixing.

An explanation for the impoverished biota in Deep Lake is not obvious from the chemical and physical data. Nutrient levels were the same as in sea water, the lake was oxygenated throughout, the pH was favourable, sufficient light was available for photosynthesis (R. Williams, pers. comm.) and water temperatures in the epilmnion were above $0^{o}C$ for most of each summer.

The salinity and trace metal concentrations were possible inhibitors of biological activity but comparison with the more productive Dead Sea, which is more saline and has considerably higher trace metal concentrations, suggests that these two factors were not important. However, R. Hand (pers. comm.) found that heterotrophic bacteria from Deep Lake multiplied only after dilution of the water.

A simple explanation is not apparent and it could be that low water temperatures, high salinities and some of the other factors mentioned above interact to inhibit biological activity.

8. ACKNOWLEDGEMENTS

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APPENDIX A

Deep Lake temperature profiles (^oC)

Depth (m)	1973									
	11 Oct	18 Oct	23 Oct	11 Nov	21 Nov	3 Dec	8 Dec	11 Dec	18 Dec	27 Dec
0	-	-	-	- 2.9	- 1.8	+ 0.1	-	+ 3.5	+ 4.8	+ 6.4
1	-11.2	-10.1	- 9.5	- 2.8	- 1.8	+ 0.1	+ 1.8	+ 3.5	+ 4.8	+ 7.5
2	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	+ 3.1	-	+ 6.9
4	-	-	-	-	-	-	-	+ 2.8	+ 4.4	+ 6.4
5	-	-10.5	-10.1	- 3.0	-	- 0.1	+ 0.1	+ 2.4	-	+ 5.7
6	-	-	-	- 3.9	-	-	-	+ 1.4	+ 3.3	+ 4.7
7	-	-	-	-	-	-	-	-	-	+ 3.1
8	-	-	-	-	- 1.8	-	-	+ 0.6	+ 1.3	+ 2.4
9	-	-	-	-	- 2.3	-	-	-	-	+ 1.6
10	-11.2	-10.8	-10.6	- 5.7	- 4.0	- 0.3	- 0.3	+ 0.3	+ 0.6	+ 1.2
11	-	-	-	- 5.9	- 5.3	- 0.3	-	+ 0.2	-	+ 0.7
12	-	-	-	- 6.2	- 5.6	- 0.7	-	+ 0.1	+ 0.1	- 0.1
13	-14.2	-	-11.1	- 6.6	- 6.1	- 1.7	-	- 2.2	- 1.4	- 1.6
14	-	-11.5	-11.5	- 7.0	- 6.5	- 5.8	-	- 5.2	- 4.1	- 3.9
15	-	-12.8	-12.6	- 7.4	- 7.1	- 6.1	- 6.3	- 5.9	- 6.3	- 5.1
16	-	-14.5	-14.4	- 7.7	- 7.5	- 7.3	-	- 6.9	- 7.0	- 6.5
17	-	-	-14.8	- 8.1	- 8.1	- 7.8	-	- 7.3	- 7.4	- 7.5

18	-	-	-	- 8.9	- 9.1	- 8.8	-	- 8.5	- 8.5	- 8.3
19	-	-	-	-10.9	-10.8	-10.7	-	-10.4	-10.4	-10.3
20	-	-15.0	-15.1	-13.5	-13.0	-12.2	-12.2	-11.7	-11.8	-11.6
21	-	-	-	-	-14.1	-13.3	-	-13.1	-12.8	-12.5
22	-	-	-	-	-14.5	-14.0	-	-13.7	-	-13.2
23	-	-	-	-	-14.7	-	-	-14.1	-13.8	-
24	-	-	-	-	-	-	-	-	-	-
25	-	-	-15.3	-14.9	-14.8	-14.3	-14.5	-14.3	-	-14.0
26	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-15.0	-	-	-	-14.3	-
29	-	-	-	-	-	-	-	-	-	-
30	-15.1	-	-15.1	-14.8	-14.8	-14.3	-14.5	-14.3	-14.1	-14.1
31	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-
33	-	-15.1	-15.1	-	-	-	-	-	-	-
34	-	-	-	-14.5	-14.7	-14.0	-14.2	-14.2	-13.5	-13.7

APPENDIX A (Continued)

Depth (m)	1974									
	7 Jan	13 Jan	21 Jan	29 Jan	13 Feb	18 Feb	21 Mar	3 Apr	26 Apr	13 May
0	+ 8.1	+ 6.1	-	+ 9.2	+ 4.1	+ 2.9	- 1.8	- 3.8	-	- 9.7
1	+ 8.1	+ 6.1	+10.0	+ 9.2	+ 4.1	+ 2.9	-	- 3.7	- 7.3	- 9.7
2	+ 8.1	+ 6.1	-	+ 9.2	+ 4.0	+ 2.9	- 1.8	- 3.7	- 7.3	- 9.7
3	+ 7.8	+ 6.1	-	+ 9.2	+ 4.0	+ 3.0	-	- 3.8	- 7.3	- 9.7
4	+ 7.4	+ 6.1	-	+ 9.2	+ 4.0	+ 2.9	- 1.8	- 3.8	- 7.3	- 9.7
5	+ 6.0	+ 5.4	+10.0	+ 9.2	+ 4.0	+ 2.9	-	- 3.8	- 7.3	- 9.7
6	+ 4.6	+ 3.8	+ 9.2	+ 9.1	+ 3.8	+ 2.9	- 1.8	- 3.8	- 7.3	- 9.7
7	+ 2.9	+ 1.8	+ 6.7	+ 7.5	+ 3.8	+ 2.9	-	- 3.8	- 7.3	- 9.7
8	+ 2.1	+ 0.4	+ 5.4	+ 5.8	+ 3.8	+ 2.9	- 1.8	- 3.8	- 7.3	- 9.7
9	+ 1.6	+ 0.1	+ 4.3	+ 4.7	+ 3.8	+ 2.9	-	- 3.8	- 7.3	- 9.7
10	+ 1.2	- 0.6	+ 3.7	+ 3.9	+ 3.8	+ 2.9	- 1.8	- 3.8	- 7.3	- 9.7
11	+ 0.7	+ 0.4	+ 3.0	+ 3.1	+ 3.8	+ 2.9	-	- 3.8	- 7.3	- 9.7
12	- 0.4	- 0.7	+ 2.0	+ 2.1	+ 3.8	+ 2.9	- 1.8	- 3.8	- 7.3	- 9.7
13	- 2.8	- 1.7	- 0.1	- 0.4	+ 3.6	+ 2.9	-	- 3.8	- 7.3	- 9.7
14	- 5.0	- 3.9	- 2.5	- 2.7	+ 0.9	+ 2.9	- 1.8	- 3.8	- 7.3	- 9.7
15	- 5.5	- 5.6	- 4.5	- 4.4	- 3.4	+ 1.8	-	- 3.8	- 7.3	- 9.7
16	- 7.4	- 6.5	- 5.8	- 5.5	- 5.0	- 4.5	- 1.8	- 3.8	- 7.3	- 9.7
17	- 8.4	- 7.5	- 6.8	- 6.7	- 6.1	- 6.0	-	- 3.8	- 7.3	- 9.7

18	- 9.4	- 8.9	- 8.0	- 7.9	- 7.8	- 7.5	- 2.5	- 4.0	- 7.3	- 9.7
19	-10.8	-10.2	- 9.4	- 9.5	- 9.3	- 8.8	- 7.5	- 8.0	- 7.4	- 9.7
20	-11.6	-11.7	-11.1	-11.0	-10.7	-10.3	-11.2	-10.7	- 7.5	- 9.7
21	-13.1	-12.6	-12.0	-12.2	-11.5	-11.4	-11.9	-11.4	- 8.2	- 9.7
22	-13.9	-13.3	-12.7	-12.7	-12.5	-12.5	-12.4	-12.3	-11.7	- 9.7
23	-14.3	-13.8	-13.2	-13.2	-12.9	-12.9	-	-12.8	-12.4	- 9.8
24	-14.5	-	-13.5	-13.5	-13.2	-13.1	-13.1	-13.2	-12.8	-12.1
25	-14.8	-14.1	-13.8	-13.6	-13.4	-13.4	-	-13.4	-13.2	-13.3
26	-	-	-13.9	-13.8	-13.5	-13.5	-13.4	-13.6	-13.4	-13.5
27	-	-	-14.0	-13.9	-13.6	-13.8	-	-13.8	-13.5	-13.6
28	-	-	-14.1	-14.0	-13.7	-13.8	-13.6	-13.8	-13.6	-13.7
29	-	-	-14.1	-14.0	-13.7	-13.9	-	-13.8	-13.6	-13.7
30	-	-14.3	-13.9	-13.8	-13.6	-13.8	-13.6	-13.7	-13.3	-13.6
31	-	-	-13.8	-13.6	-13.5	-13.8	-	-13.7	-13.5	-13.6
32	-	-	-13.8	-13.5	-13.4	-13.7	-13.6	-13.7	-13.5	-13.6
33	-	-	-13.7	-13.4	-13.4	-13.7	-	-13.6	-13.4	-13.6
34	-14.8	-13.8	-13.6	-13.3	-13.3	-13.6	-13.0	-13.4	-13.3	-13.5

APPENDIX A (Continued)

Depth (m)	1974 (Continued)									
	21 May	14 Jul	11 Aug	20 Aug	4 Sep	21 Sep	30 Sep	11 Oct	17 Oct	30 Oct
0	-	-	-	-	-	-	-	-	-	-
1	-10.8	-11.4	-13.4	-14.2	-12.3	-14.4	-12.4	-10.2	- 8.9	- 4.8
2	-	-	-	-	-	-14.4	-	-	-	-
3	-	-	-	-	-	-	-	-	- 8.9	- 5.7
4	-	-	-	-	-	-	-	-	-	-
5	-10.8	-11.5	-13.4	-14.2	-12.3	-14.4	-13.2	-10.5	- 9.1	- 6.6
6	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-11.2	- 9.2	-
8	-	-	-	-	-	-	-	-	-	- 7.7
9	-	-	-	-	-	-	-	-	-	-
10	-10.8	-11.5	-13.4	-14.2	-12.3	-14.4	-13.5	-11.8	- 9.5	- 8.5
11	-	-	-	-	-	-	-	-	- 9.7	- 9.0
12	-	-	-	-	-	-	-	-	-10.3	-
13	-	-	-	-	-	-	-	-	-11.5	-10.7
14	-	-	-	-	-	-	-	-	-12.0	-
15	-10.8	-11.5	-13.4	-14.2	-12.4	-14.4	-13.8	-12.3	-12.1	-11.7
16	-	-	-	-	-12.4	-	-	-	-12.1	-
17	-	-	-	-	-12.6	-	-	-	-12.9	-

18	-	-	-	-	-13.0	-	-	-	-13.0	-12.6
19	-	-	-	-	-13.2	-	-	-	-13.2	-
20	-10.8	-11.5	-13.4	-14.2	-13.6	-14.4	-14.0	-13.6	-13.5	-13.0
21	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-13.9	-	-	-	-13.8	-
23	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-
25	-11.5	-11.5	-13.4	-14.2	-14.1	-14.4	-14.2	-14.0	-14.0	-13.7
26	-	-11.5	-13.4	-	-	-	-	-	-	-
27	-	-12.5	-13.4	-	-	-	-	-	-	-
28	-	-12.7	-13.4	-	-	-	-	-	-	-
29	-	-13.0	-13.4	-	-	-	-	-	-	-
30	-13.3	-13.3	-	-14.2	-14.1	-14.4	-14.2	-14.1	-14.0	-13.8
31	-	-	-	-13.8	-14.0	-14.4	-	-13.8	-14.0	-13.8
32	-	-	-	-13.6	-13.5	-14.3	-	-13.5	-13.5	-13.3
33	-	-	-	-13.6	-	-13.7	-	-13.3	-13.2	-13.6
34	-13.4	-13.4	-13.4	-13.6	-13.5	-13.6	-13.3	-	-13.1	-

APPENDIX A (Continued)

Depth (m)	1974						1975			
	18 Nov	26 Nov	2 Dec	13 Dec	24 Dec	26 Dec	2 Jan	14 Jan	8 Feb.	17 Feb
0	-	-	-	-	-	-	-	-	-	-
1	- 1.1	+ 0.8	+ 3.5	+ 8.7	+ 7.1	+ 7.4	+ 7.2	+ 7.0	+ 5.5	+ 3.2
2	-	-	-	+ 8.5	-	-	-	-	-	-
3	-	-	-	+ 8.1	-	-	-	-	-	-
4	-	-	+ 3.2	+ 7.0	-	-	-	-	-	-
5	- 1.4	+ 0.2	+ 2.5	+ 5.7	+ 6.8	+ 7.1	+ 6.5	+ 6.0	+ 5.5	+ 3.2
6	- 1.9	+ 0.1	+ 2.2	+ 4.9	+ 6.7	-	-	-	-	-
7	- 2.0	- 0.4	+ 1.9	+ 3.2	+ 4.7	-	-	-	-	-
8	- 2.7	- 1.8	+ 0.6	+ 1.8	+ 2.7	-	-	-	-	-
9	- 4.2	- 4.1	- 2.8	- 1.0	- 0.3	-	-	+ 5.2	-	-
10	- 6.9	- 6.0	- 3.7	- 2.9	- 3.0	-	- 2.0	+ 2.7	+ 5.3	+ 3.2
11	- 7.7	- 7.5	- 6.0	- 4.7	- 4.6	-	-	- 2.7	+ 5.0	+ 3.2
12	- 8.6	- 8.6	- 7.0	- 6.2	- 6.2	-	-	- 4.5	- 0.6	+ 3.2
13	- 9.6	- 9.4	- 8.2	- 7.4	- 7.3	-	-	- 6.1	- 4.4	+ 3.0
14	-10.3	-10.1	- 9.5	- 8.4	- 8.2	-	-	- 7.2	-	- 5.1
15	-10.9	-10.7	- 9.6	- 9.2	- 9.0	- 9.0	- 8.3	- 7.6	- 6.3	- 5.9
16	-11.2	-	-10.4	- 9.7	-	-	-	-	-	-
17	-11.5	-11.0	-11.0	-10.3	-10.1	-	-	-	-	-

18	-11.8	-	-11.0	-10.9	-	-	-	-	-	-
19	-12.0	-12.0	-11.5	-11.3	-	-	-	-	-	-
20	-12.6	-12.3	-12.0	-11.5	-11.5	-11.2	-10.3	-10.8	- 9.6	- 9.8
21	-12.7	-	-	-11.8	-	-	-	-	-	-
22	-	-	-	-12.1	-11.9	-	-	-	-	-
23	-13.1	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-
25	-13.2	-13.0	-12.7	-12.5	-12.4	-12.2	-10.7	-11.7	-11.1	-11.4
26	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-
30	-13.4	-13.3	-13.0	-12.8	-12.6	-12.6	-12.1	-12.2	-11.8	-11.7
31	-13.3	-	-13.0	-12.8	-	-	-	-	-	-
32	-13.0	-	-12.4	-12.2	-	-	-	-	-	-
33	-12.8	-12.5	-	-12.1	-12.0	-12.0	-	-	-	-11.2
34	-12.5	-	-12.1	-	-	-	-11.2	-11.5	-11.4	-

APPENDIX A (Continued)

Depth (m)	1975(Continued)									
	27 Feb	2 Mar	18 Mar	23 Mar	9 Apr	30 Apr	13 May	20 May	6 June	17 June
0	-	-	-	-	-	-	-	-10.1	-	-11.6
1	+ 2.1	+ 1.1	- 2.1	- 3.2	- 4.7	- 8.5	- 9.4	-10.1	- 10.4	-11.3
2	-	-	-	-	-	-	-	-10.1	-	-
3	+ 2.2	-	-	- 3.0	-	-	-	-10.1	- 10.4	-11.3
4	-	-	-	-	-	-	-	-	-	-
5	+ 2.2	+ 1.1	- 2.2	- 3.1	- 4.8	- 8.5	- 9.4	-10.1	- 10.4	-11.3
6	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	+ 2.2	+ 1.1	- 2.2	- 3.0	- 4.8	- 8.5	-	-10.1	- 10.4	-11.2
11	-	-	-	-	-	-	-	-	-	-
12	-	+ 0.9	-	-	-	-	-	-	-	-
13	+ 2.2	+ 0.9	-	-	-	-	-	-	-	-
14	- 1.9	+ 0.9	-	-	-	-	-	-	-	-
15	- 5.6	- 0.7	- 2.3	- 3.1	- 4.8	- 8.5	- 9.4	-10.1	- 10.4	-11.2
16	-	- 6.2	- 2.3	-	- 4.8	-	-	-	-	-
17	-	-	- 2.3	- 3.2	- 4.8	-	-	-	-	-

18	-	-	-7.5	-5.2	-4.8	-8.5	-	-	-	-
19	-	-	-	-9.1	-6.0	-8.5	-	-	-	-
20	-9.3	-9.4	-9.0	-8.7	-6.8	-8.5	-9.4	-10.1	-10.4	-11.2
21	-	-	-	-	-9.1	-8.5	-	-	-	-
22	-	-	-	-9.8	-	-	-	-	-	-
23	-	-	-	-10.2	-	-	-	-	-	-
24	-	-	-	-10.2	-	-	-	-	-	-
25	-11.1	-11.0	-10.9	-11.7	-10.2	-8.5	-9.4	-10.1	-10.4	-11.2
26	-	-	-	-11.0	-	-8.8	-9.4	-10.1	-	-
27	-	-	-	-	-	-10.6	-9.4	-	-	-
28	-	-	-	-	-	-	-9.4	-10.1	-	-
29	-	-	-	-	-	-	-	-	-	-
30	-11.6	-11.6	-11.4	-11.3	-11.2	-11.1	-9.4	-10.1	-10.4	-11.2
31	-	-	-	-	-	-	-9.4	-10.2	-10.4	-11.2
32	-	-	-11.3	-	-11.2	-	-11.2	-10.9	-10.4	-11.2
33	-11.1	-10.9	-	-11.2	-	-11.2	-11.2	-11.3	-10.9	-11.2
34	-	-	-	-	-	-	-	-11.3	-	-11.2

APPENDIX A(Continued)

Depth (m)	1975(Continued)									
	25 June	16 Jul	1 Aug	20 Aug	30 Aug	9 Sep	23 Sep	13 Oct	27 Oct	5 Nov
0	-	-	-	-	-16.5	-	-	-	-	-
1	-12.3	-13.5	-14.5	-16.0	-16.4	-16.7	-16.2	-12.2	- 7.3	- 4.8
2	-	-	-	-	-	-	-	-	-	-
3	-12.3	-	-	-	-	-	-	-12.4	-	- 4.8
4	-	-	-	-	-	-	-	-	-	-
5	-12.3	-13.5	-14.6	-16.0	-16.4	-16.7	-16.2	-12.5	- 9.6	- 4.9
6	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	- 5.0
9	-	-	-	-	-	-	-	-	-	- 6.9
10	-12.3	-13.5	-14.7	-16.0	-16.4	-16.7	-16.5	-14.4	-13.1	-10.7
11	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-13.4
13	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-
15	-12.3	-13.5	-14.8	-16.0	-16.4	-16.7	-16.6	-15.1	-14.7	-14.3
16	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-

18	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-
20	-12.3	-13.5	-14.9	-16.0	-16.4	-16.7	-16.8	-15.5	-15.2	-14.9
21	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-
25	-12.3	-13.5	-15.0	-16.0	-16.4	-16.7	-17.0	-15.7	-15.6	-15.3
26	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-
28	-	-	-	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-	-
30	-12.3	-13.5	-15.7	-16.0	-16.4	-16.7	-17.2	-15.8	-15.7	-15.3
31	-12.3	-	-	-	-	-	-	-	-	-
32	-12.3	-	-	-	-	-	-	-	-	-
33	-12.3	-	-	-	-16.4	-16.7	-17.2	-15.8	-15.7	-15.4
34	-12.2	-13.5	-	-	-16.1	-	-	-	-	-

APPENDIX A(Continued)

Depth (m)	1975(Continued)				1976		
	19 Nov	18 Nov	10 Dec	23 Dec	12 Jan	25 Jan	28 Jan
0	-	+ 2.6	+ 3.3	+ 5.0	+ 5.7	+ 5.6	-
1	- 1.6	+ 2.6	-	+ 5.0	+ 5.7	-	+ 6.0
2	-	-	-	-	-	-	-
3	- 1.7	+ 2.6	+ 3.3	-	-	-	+ 5.9
4	-	-	-	-	-	-	-
5	- 2.0	+ 2.0	+ 3.3	+ 4.5	+ 5.6	+ 5.5	+ 6.0
6	-	-	-	-	-	-	-
7	-	-	+ 2.0	+ 4.3	+ 5.6	-	+ 6.0
8	-	- 1.0	-	-	-	-	-
9	-	-	- 0.7	+ 2.9	+ 5.6	-	-
10	- 2.8	- 2.2	- 1.7	- 2.0	+ 5.2	+ 5.0	+ 6.0
11	- 8.9	-	- 6.8	- 4.7	- 3.4	+ 2.1	+ 4.0
12	-12.2	-	-10.1	- 8.2	- 7.0	- 6.1	- 3.8
13	-12.7	-11.4	-	- 9.0	- 9.3	- 8.3	-
14	-	-	-	-	-	-10.4	-
15	-13.6	-12.9	-12.2	-11.4	-10.7	-10.7	- 6.8
16	-	-	-	-	-	-	-
17	-	-13.5	-13.1	-12.3	-11.9	-11.7	-

18	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-
20	-14.4	-13.8	-13.6	-13.0	-12.7	-12.6	-10.2
21	-	-	-	-	-	-	-
22	-	-14.2	-	-	-	-	-
23	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-
25	-14.8	-14.5	-14.2	-13.8	-13.6	-13.5	-11.7
26	-	-	-	-	-	-	-
27	-	-14.6	-	-	-	-	-
28	-	-	-	-	-	-	-
29	-	-	-	-	-	-	-
30	-15.0	-14.6	-14.4	-14.0	-13.7	-13.6	-11.9
31	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-
33	-15.0	-14.6	-14.5	-14.0	-13.8	-13.7	-11.3
34	-	-	-14.6	-	-	-	-

APPENDIX B

Variation of relative light intensity with depth in Deep Lake
(% surface light)

Depth (m)	1973							
	18 Oct (No filter)	23 Oct (No filter)	15 Nov (No filter)	21 Nov (No filter)	21 Nov* (No filter)	3 Dec (No filter)	3 Dec* (No filter)	11 Dec (No filter)
0^+	100	100	100	100	100	100	100	100
1	90.3	89.6	89.5	87.0	90.1	77.8	67.8	91.1
2	81.6	72.8	78.9	78.0	81.5	76.6	70.3	83.8
3	74.3	83.2	73.7	73.7	73.8	74.2	69.5	68.1
4	68.0	69.8	73.7	68.3	68.2	70.6	64.4	66.0
5	61.2	61.2	63.2	63.9	62.3	63.3	59.3	60.7
6	56.8	56.7	57.9	56.3	56.6	59.7	54.2	53.4
7	51.0	52.6	52.6	49.9	51.3	54.3	49.2	49.2
8	44.7	43.7	47.4	44.8	45.0	47.1	42.4	44.0
9	38.8	35.1	44.7	40.9	44.7	42.1	39.0	38.7
10	36.4	32.1	39.5	39.4	41.4	36.7	35.6	33.5
11	33.5	25.7	36.8	36.8	37.7	33.0	32.2	30.4
12	30.6	24.3	34.2	34.3	33.8	29.9	28.0	28.1
13	27.7	24.3	28.9	30.7	30.1	26.6	26.3	25.5
14	24.8	24.3	28.9	27.9	26.8	24.4		22.6
15	22.8	20.1	26.3	23.8	23.8	19.5		20.2

16	20.4	20.1	26.1	21.7	17.6	18.1
17	18.4	20.1	23.9	21.0	19.0	16.4
18	17.0	16.0	21.1	18.9	17.6	14.5
19	-	16.0	19.2	15.9	14.9	13.3
20	-	11.9	17.1	14.3	13.1	11.9
21	-	-	15.5	13.0	-	-
22	-	-	13.4	12.0	10.9	9.5
23	-	-	12.1	10.7	-	-
24	-	-	10.8	9.7	9.0	7.9
25	-	8.2	9.5	9.2	-	-
26	-	-	8.9	-	7.7	6.4
27	-	-	8.4	7.7	-	-
28	-	-	7.9	-	6.3	5.2
29	-	-	7.4	6.1	-	-
30	-	4.1	6.6	-	4.5	4.8
31	-	-	6.3	4.1	-	-
32	-	-	5.3	-	4.1	3.8
33	-	-	4.7	3.1	-	-

+ The amount of surface light (Om) was determined graphically by the method of Vollenweider (1974).

* Light profiles measured at sampling station B where the bottom depth was about 15. All other measurements were made at Station A.

APPENDIX B (Continued)

Depth (m)	1974							
	7 Jan Ø (No filter)	13 Jan (No filter)	21 Jan (No filter)	18 Feb (No filter)	18 Feb (Red filter)	18 Feb (Green filter)	18 Feb (Blue filter)	17 Apr (No filter)
0	100	100	100	100	100	100	100	100
1	91.4	86.1	68.3	68.5	44.8	64.4	76.4	-
2	79.2	75.9	64.5	65.6	34.4	59.1	56.9	82.7
3	65.0	67.8	61.7	63.6	29.6	56.6	60.1	73.3
4	56.9	61.8	61.2	62.7	24.8	51.5	59.4	66.7
5	48.7	54.7	57.4	57.7	19.2	48.9	56.3	57.3
6	42.1	48.6	51.9	52.9	14.4	51.7	52.1	52.0
7	40.6	42.5	46.4	48.0	10.4	47.2	47.2	46.7
8	36.0	37.5	42.1	44.0	6.0	42.8	43.4	42.7
9	31.0	35.4	37.2	39.2	4.4	39.2	39.2	38.7
10	26.9	34.9	32.8	35.2	3.0	33.1	35.4	36.0
11	-	28.9	30.1	32.3	1.9	30.9	31.3	32.0
12	-	25.1	26.8	28.4	1.2	28.4	27.8	25.9
13	-	22.0	24.0	25.6	0.8	25.6	25.0	20.4
14	-	19.0	21.0	23.5	0.5	23.1	22.6	20.1
15	13.7	16.5	19.1	20.6	0.2	20.8	20.1	19.9
16	-	14.7	16.9	18.6	B.L.D.	18.4	18.1	17.5
17	-	12.9	15.3	15.6	-	16.7	16.0	15.6

19	-	10.1	13.1	14.8	-	13.6	12.8	12.7
20	9.6	8.9	11.5	13.1	-	12.1	11.8	11.6
21	-	8.1	9.8	11.6	-	10.8	10.4	8.7
22	-	7.1	8.7	10.3	-	9.7	9.4	9.6
23	-	6.3	7.9	9.2	-	8.9	8.7	8.5
24	-	5.6	7.4	8.1	-	7.8	7.6	7.7
25	5.6	5.1	6.9	7.3	-	7.2	6.9	6.8
26	-	4.8	5.9	6.5	-	6.6	6.3	6.1
27	-	4.1	5.4	5.9	-	5.7	5.9	5.6
28	-	3.8	5.0	5.2	-	5.3	5.2	5.2
29	-	3.5	4.5	4.8	-	4.9	4.9	4.7
30	-	3.0	4.0	4.4	-	4.2	4.2	4.0
31	-	2.8	3.5	3.9	-	3.8	3.1	3.7
32	-	2.5	3.0	3.5	-	3.4	2.5	3.3
33	-	1.8	3.0	3.1	-	-	-	3.2

Ø Measurement of light transmission was commenced at 20:00 h when the sun was low on the horizon.

APPENDIX B (Continued)

Depth (m)	1974 (Continued)			1975				
	17 Apr (Red filter)	17 Apr (Green filter)	17 Apr (Blue filter)	19 May (No filter)	19 May (Red filter)	19 May (Green filter)	19 May (Blue filter)	23 Dec (No filter)
0	100	100	100	100	100	100	100	100
1	66.7	-	-	81.4	72.0	92.0	95.4	85.6
2	33.3	79.6	88.7	83.3	46.7	80.6	84.4	-
3	14.4	76.4	78.2	74.2	35.7	75.7	73.4	78.0
4	12.2	70.1	75.0	70.5	24.7	71.2	68.8	-
5	7.7	66.2	71.0	66.3	19.2	65.3	64.2	66.4
6	5.5	59.2	65.3	60.6	13.7	59.7	-	-
7	3.9	54.8	58.9	55.3	9.3	54.9	55.0	52.0
8	3.1	49.0	54.0	51.1	6.0	50.3	-	-
9	1.9	44.6	50.0	47.3	4.9	46.5	-	-
10	B.L.D.	41.4	45.2	41.7	2.7	41.7	41.3	41.6
11	-	36.9	41.1	38.5	B.L.D.	38.2	-	-
12	-	34.4	38.7	35.0	-	34.7	-	-
13	-	31.8	35.5	32.1	-	-	-	-
14	-	29.3	32.3	29.9	-	29.5	-	-
15	-	27.4	29.0	28.2	-	26.4	27.5	28.0
16	-	24.8	26.6	27.4	-	-	-	-
17	-	22.3	24.2	23.5	-	22.6	-	-

18	-	20.4	22.6	21.4	-	-	-	-
19	-	18.5	21.0	19.7	-	-	-	-
20	-	17.2	18.2	17.1	-	17.4	17.0	17.6
21	-	15.9	16.4	16.2	-	-	-	-
22	-	15.3	15.5	15.0	-	-	-	-
23	-	14.0	13.4	13.7	-	-	-	-
24	-	12.7	12.7	12.4	-	-	-	-
25	-	10.3	11.4	11.5	-	11.8	11.0	11.4
26	-	9.2	10.5	10.5	-	-	-	-
27	-	8.4	9.5	9.8	-	-	-	-
28	-	7.9	8.6	9.0	-	-	-	-
29	-	7.2	-	8.3	-	-	-	-
30	-	6.5	-	7.5	-	7.6	6.4	7.6
31	-	-	-	6.9	-	-	-	-
32	-	-	-	6.4	-	-	-	-
33	-	-	-	5.8	-	5.6	4.6	5.8

APPENDIX C

Dissolved oxygen concentrations in Deep Lake water

Depth (m)	1973							
	9 Aug ml/1(°C)	19 Sept ml/1(°C)	11 Oct ml/1(°C)	23 Oct ml/1(°C)	11 Nov ml/1(°C)	21 Nov ml/1(°C)	8 Dec ml/1(°C)	11 Dec[1] ml/1(°C)
0	2.44(-18.3)	2.46(-15.0)	-	-	-	-	-	-
1	-	-	2.25(-11.2)	2.32(-9.5)	2.11(-2.8)	1.99(-1.8)	2.09(+1.8)	2.20(+4.0)
3	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	2.07(+0.8)	-
6	-	-	-	-	2.13(-3.9)	-	-	-
7	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	2.20(+0.7)
9	-	-	-	-	-	-	-	-
10	-	-	-	-	-	2.13(-4.0)	2.09(-0.3)	-
11	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-
13	-	-	-	2.34(-11.1)	-	-	-	-
14	-	-	-	-	-	-	-	2.35(-5.2)
15	-	-	2.42(-14.8)	-	-	2.15(-7.1)	2.22(-6.3)	-
16	-	-	-	-	2.21(-7.7)	-	-	-
18	-	-	-	2.51(-15.0)	-	-	-	-

20	-	-	-	-	-	-	2.42(-12.2)	-
21	-	-	-	-	2.44(-14.0)	2.42(-14.1)	-	-
23	-	-	-	-	-	-	-	-
25	-	-	-	-	-	2.43(-14.8)	2.42(-14.5)	-
27	-	-	-	-	-	-	-	-
30	-	-	2.23(-15.1)	-	-	-	2.36(-14.5)	-
32	-	-	-	2.31(-15.1)	-	-	-	-
33	-	-	-	-	-	-	-	-
34	-	-	-	-	2.04(-14.5)	2.22(-14.7)	2.27(-14.2)	-

APPENDIX C (Continued)

Depth (m)	1973				1974		1975	
	11 Dec [2] ml/l(°C)	18 Dec [2] ml/l(°C)	27 Dec [3] ml/l(°C)	27 Dec [4] ml/l(°C)	13 Jan ml/l(°C)	20 Aug ml/l(°C)	6 June ml/l(°C)	5 Nov ml/l(°C)
0	-	-	-	-	-	-	-	-
1	-	-	-	-	2.03(+11.5)	-	2.42(-10.4)	2.14(-4.8)
3	2.10(+3.5)	1.96(+4.5)	-	-	-	-	-	-
5	-	1.93(+4.0)	2.11(+6.2)	1.83(+5.8)	2.03(+10.0)	2.30(-14.2)	2.30(-10.4)	2.18(-4.9)
6	-	-	-	-	-	-	-	-
7	2.10(+0.2)	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-
9	-	2.07(+0.5)	-	-	-	-	-	-
10	-	-	2.17(+1.0)	1.91(+1.0)	1.97(+2.0)	2.30(-14.2)	2.30(-10.4)	2.37(-10.7)
11	-	2.14(0.0)	-	-	-	-	-	-
12	2.04(-0.3)	-	-	-	-	-	-	-
13	-	2.11(-2.2)	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-
15	-	2.38(-6.2)	2.40(-5.2)	2.11(-5.2)	2.22(-5.0)	-	2.32(-10.4)	2.61(-14.3)
16	-	-	-	-	-	-	-	-
18	2.30(-9.1)	-	-	-	-	-	-	-

20	-	2.49(-11.3)	2.54(-10.2)	2.51(-12.2)	2.37(-11.0)	-	-	-
21	-	-			-	-	-	-
23	2.58(-14.0)	-			-	-	-	-
25		-			2.43(-13.5)	2.30(-14.2)	2.37(-10.4)	2.52(-15.3)
27		2.64(-14.2)			-	-	-	-
30					2.34(-13.8)	-	2.32(-10.4)	2.48(-15.3)
32					-	-	-	-
33					-	-	2.34(-10.4)	2.59(-15.4)
34					2.22(-13.8)	-	-	-

1. Samples collected from Station B.
2. Bottom samples collected from near Station D.
3. Samples collected from Station D (morning).
4. Samples collected from Station D (afternoon).

All other samples were collected from the centre of lake (Station A).

APPENDIX D

Concentrations of major ions in Deep Lake

Date	Depth (m)	Sodium Na^+ (g/1)	Potassium K^+ (g/1)	Magnesium Mg^{2+} (g/1)	Calcium Ca^{2+} (g/1)	Chloride Cl^- (g/1)	Bicarbonate HCO_3^- (g/1)
23 Oct 1973	1	73.1	4.1	13.8	2.2	160.5	-
	18	73.1	4.1	12.5	2.2	159.7	-
	32	72.2	4.1	14.4	2.2	161.9	-
11 Nov 1973	1	72.7	4.1	14.0	2.3	158.3	-
	6	71.8	4.0	14.0	2.2	157.6	-
	16	72.2	4.0	14.0	2.2	156.2	-
	21	71.8	4.0	13.5	2.2	157.6	-
	33	72.7	4.1	13.5	2.2	162.6	-
21 Jan 1974	1	70.4	4.0	13.8	2.2	154.8	-
	10	72.7	4.1	13.5	2.2	158.3	-
	18	73.6	4.1	14.4	2.3	161.2	-
	22	72.2	4.1	13.5	2.1	160.4	-
	34	72.7	4.1	14.4	2.2	162.6	-
21 Jan 1974	1	67.8	4.31	11.6	2.28	165.0	-
	5	66.3	4.32	11.1	2.49	-	-
	10	66.9	-	11.4	2.40	-	-
	18	66.8	4.34	11.9	2.45	-	-

	22	66.8	4.27	11.6	2.45	-	-
	30	-	-	-	-	167.4	-
	34	68.0	4.41	11.9	2.33	-	-
18 Feb 1974	10	68.3	4.20	12.0	2.49	164.6	0.279
	20	66.5	4.20	12.0	2.47	165.0	0.280
21 Mar 1974	5	52.4	4.20	11.6	2.41	164.9	0.278
	30	64.5	4.32	11.7	2.39	167.4	0.278
3 Apr 1974	1	66.5	4.34	11.6	2.47	164.9	0.277
	5	66.5	4.32	11.3	2.30	165.1	-
	10	65.0	4.39	11.3	2.45	165.0	0.278
	15	65.8	4.35	11.6	2.36	164.9	-
	20	65.3	4.30	11.4	2.34	164.6	-
	25	65.3	4.33	11.7	2.37	164.7	-
	30	66.0	4.36	12.2	2.37	167.1	0.280
	34	67.2	4.37	11.6	2.36	167.9	-
26 Apr 1974	1	66.0	4.38	11 7	2.49	164.8	0.278
	5	66.8	4.38	11.8	2.50	165.0	-
	10	65.9	4.38	11.6	2.48	165.0	0.279
	15	66.1	4.25	12.0	2.47	165.0	-
	20	67.1	4.33	12.6	2.39	165.0	-
	25	67.7	4.43	13.0	2.47	164.9	-
	30	65.5	4.48	12.0	2.41	166.8	0.280
	34	65.0	4.45	11.8	2.31	167.6	-

APPENDIX D (Continued)

Date	Depth (m)	Sodium Na^+ (g/1)	Potassium K^+ (g/1)	Magnesium Mg^{2+} (g/1)	Calcium Ca^{2+} (g/1)	Chloride Cl^- (g/1)	Bicarbonate HCO_3^- (g/1)
21 May 1974	1	64.4	4.19	11.8	2.41	165.1	0.324
	5	-	4.19	-	-	164.8	-
	10	64.5	4.20	11.7	2.50	165.0	0.277
	15	-	4.20	-	-	165.1	-
	20	-	4.20	-	-	165.2	-
	25	-	4.20	-	-	165.2	-
	30	65.4	4.24	11.9	2.36	167.1	0.282
	34	-	4.24	-	-	167.6	-
14 July 1974	1	64.2	4.28	11.5	2.27	164.9	0.274
	10	66.6	-	11.8	2.37	165.0	0.279
	30	67.4	4.28	12.0	2.08	167.1	0.279
11 Aug 1974	1	-	4.16	-	-	164.5	0.277
	5	-	4.16	-	-	164.5	-
	10	-	4.17	-	-	164.6	0.282
	15	-	4.17	-	-	164.5	-
	20	-	4.17	-	-	164.5	0.275
	25	-	4.16	-	-	164.5	-
	30	-	4.17	-	-	164.5	0.276

	34	-	4.24	-	-	167.8	-
4 Sept 1974	1	-	4.26	-	-	165.2	-
	5	-	4.24	-	-	165.2	-
	10	-	4.20	-	-	165.1	-
	15	-	4.24	-	-	165.2	-
	20	-	4.28	-	-	165.2	-
	25	-	4.20	-	-	165.2	-
	30	-	4.26	-	-	165.9	-
	34	-	4.29	-	-	167.9	-
18 Nov 1974	1	-	4.20	-	-	165.1	-
	5	-	4.23	-	-	165.1	-
	10	-	4.19	-	-	165.2	-
	15	-	4.28	-	-	165.1	-
	20	-	4.22	-	-	165.1	-
	25	-	4.20	-	-	165.1	-
	30	-	4.23	-	-	165.2	-
	34	-	4.31	-	-	168.1	-
26 Nov 1974	1	-	4.28	-	-	164.6	-
	5	-	4.19	-	-	164.6	-
	10	-	4.21	-	-	164.6	-
	15	-	4.21	-	-	164.6	-
	20	-	4.26	-	-	164.7	-
	25	-	4.23	-	-	164.7	-
	30	-	4.22	-	-	164.6	-
	34	-	4.28	-	-	167.7	-

APPENDIX D (Continued)

Date	Depth (m)	Sodium Na^+ (g/1)	Potassium K^+ (g/1)	Magnesium Mg^{2+} (g/1)	Calcium Ca^{2+} (g/1)	Chloride Cl^- (g/1)	Bicarbonate HCO_3^- (g/1)
2 Dec 1974	1	69.2	4.38	14.8	2.38	164.7	-
	30	69.8	4.42	14.8	2.40	165.0	-
24 Dec 1974	1	-	4.25	-	-	-	-
	5	-	4.26	-	-	-	-
	10	-	4.25	-	-	-	-
	15	-	4.27	-	-	-	-
	20	-	4.23	-	-	-	-
	25	-	4.30	-	-	-	-
	30	-	4.30	-	-	-	-
	34	-	4.29	-	-	-	-
27 Jan 1975	7.5	70.0	4.30	13.6	3.75	166.1	-
	33	72.0	4.30	13.6	3.78	168.3	-

Sulphate concentrations in Deep Lake water (g/1)

Depth (m)	2 Dec 1974	20 Aug 1975	23 Sept 1975
1	3.12	-	2.84
5	-	-	2.63
10	-	2.75	2.68
15	-	-	2.79
20	-	2.78	2.90
25	-	2.73	2.85
30	3.16	2.69	2.73
33	-	-	2.85

APPENDIX E

Concentrations of chloride in Deep Lake (g/1)

Depth	1973	1974									
(m)	13 Oct	21 Jan	18 Feb	21 Mar	13 Apr	26 Apr	21 May	12 Jul	11 Aug	4 Sept	18 Nov
0	-	-	-	-	-	-	-	-	-	-	-
1	166.3	-	-	165.0	164.9	164.8	165.1	164.9	164.5	165.2	165.1
3	-	-	-	-	-	-	-	-	-	-	-
5	-	165.0	-	164.9	165.1	165.0	164.8	-	164.5	165.2	165.1
10	-	-	164.5	164.9	165.0	165.0	165.0	165.0	164.6	165.1	165.2
15	167.7	-	-	165.0	164.9	165.0	165.1	-	164.5	165.2	165.1
20	-	-	165.0	164.9	164.6	165.0	165.2	164.8	164.5	165.2	165.1
25	-	-	-	165.0	164.7	164.9	165.2	-	164.5	165.2	165.1
30	167.3	167.4	-	167.4	167.1	166.8	167.1	167.1	164.5	165.9	165.2
33	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	167.8	167.9	167.6	167.6	167.6	167.8	167.9	168.1

Depth (m)	1974			1975						1976	
	26 Nov	2 Dec	27 Jan	27 Oct	5 Nov	19 Nov	27 Nov	10 Dec	23 Dec	13 Jan	25 Jan
0	-	-	-	-	163.5	163.7	163.8	164.5	164.4	164.0	163.9
1	164.6	-	166.0	163.3	163.6	-	163.8	-	164.4	-	-
3	-	-	166.1	-	163.5	163.6	-	-	-	-	-
5	164.6	164.8	166.1	163.1	163.6	163.6	163.8	164.3	164.3	163.9	163.9
10	164.6	-	166.1	164.1	163.6	163.6	163.8	-	-	164.1	164.0
15	164.6	-	164.9	164.3	164.2	164.5	163.9	164.5	164.6	164.6	164.6
20	164.7	-	164.9	-	164.2	164.5	164.2	-	-	164.7	164.6
25	164.7	-	164.3	164.4	164.7	164.5	164.4	164.6	164.6	164.6	164.6
30	164.6	164.5	165.8	164.1	164.4	164.5	164.6	164.6	164.5	164.6	164.6
33	-	-	168.3	-	164.7	164.5	164.8	164.7	164.6	164.7	164.6
34	167.7	-	-	-	-	-	-	164.7	-	-	-

APPENDIX F

Nutrient concentrations in Deep Lake

Date	Depth (m)	Nitrate-N (µg/l)	Nitrite-N (µg/l)	Reactive Silicate-Si (mg/l)	Phosphate-P (µg/l)	Total Phosphorus (µg/l)	Carbohydrate (as starch) (mg/l)
9 Aug 1973	0	62.3	2.1	-	B.L.D.	-	-
11 Nov 1973	1	75.6	1.4	3.51	40.3	-	-
	6	68.6	1.7	3.65	43.4	-	-
	16	67.2	2.4	3.93	38.8	-	-
	21	67.2	2.8	3.79	35.7	-	-
	34	58.8	3.8	4.35	43.4	-	-
29 Jan 1974	1	71.4	2.4	4.26	20.2	-	-
	9	71.4	2.9	4.35	16.1	-	-
	18	74.2	2.5	4.57	24.2	-	-
	22	71.4	2.7	3.42	16.7	-	-
	34	70.7	2.5	3.28	14.9	-	-
18 Feb 1974	10	74.2	2.8	2.95	44.1	-	-
	20	70.1	4.2	-		-	-
21 Mar 1974	5	75.6	2.8	2.95	44.4	-	-
	30	75.6	2.8	-	14.5	-	-

3 Apr 1974	1	75.6	2.8	2.95	31.2	-	-
	5	-	-	-	27.7	-	-
	10	75.6	2.8	-	14.5	-	-
	15	-	-	-	17.4	-	-
	20	-	-	-	33.0	-	-
	25	-	-	-	22.6	-	-
	30	75.6	2.8	2.95	12.5	-	-
	34	-	-	-	12.0	-	-
26 Apr 1974	1	75.6	2.8	2.81	B.L.D.	138	-
	5	75.6	2.8	2.81	B.L.D.	151	-
	10	74.2	2.8	2.81	B.L.D.	62	-
	15	75.6	2.8	2.95	B.L.D.	74	-
	20	75.6	2.8	2.95	B.L.D.	38	-
	25	75.6	2.8	2.95	B.L.D.	36	-
	30	72.8	2.8	3.02	B.L.D.	24	-
	34	74.2	2.8	3.02	B.L.D.	25	-
21 May 1974	1	75.6	2.8	2.53	B.L.D.	116	-
	5	75.6	2.8	-	B.L.D.	117	-
	10	75.6	2.8	2.95	B.L.D.	108	-
	15	74.2	2.8	-	B.L.D.	110	-
	20	74.2	2.8	-	B.L.D.	-	-
	25	74.2	2.8	-	B.L.D.	102	-
	30	74.2	2.8	3.02	B.L.D.	116	-
	34	70.0	2.8	-	B.L.D.	126	-

APPENDIX F (Continued)

Date	Depth (m)	Nitrate-N (µg/1)	Nitrite-N (µg/1)	Reactive Silicate-Si (mg/1)	Phosphate-P (µg/1)	Total Phosphorus (µg/1)	Carbohydrate (as starch) (mg/1)
14 July 1974	1	70.0	2.7	2.67	B.L.D.	71	-
	5	-	-	-	B.L.D.	26	-
	10	70.0	2.5	2.53	B.L.D.	78	-
	15	-	-	-	B.L.D.	65	-
	20	-	-	-	B.L.D.	118	-
	25	-	-	-	B.L.D.	65	-
	30	70.0	2.5	2.53	B.L.D.	56	-
	34	-	-	-	B.L.D.	107	-
11 Aug	1	-	-	-	1.9	95	-
	5	-	-	-	2.8	115	-
	10	-	-	-	2.5	105	-
	15	-	-	-	1.4	126	-
	20	-	-	-	1.6	124	-
	25	-	-	-	123	119	-
	30	-	-	-	119	126	-
	34	-	-	-	2.0	135	-

4 Sept 1974	1	70.0	2.5	2.53	B.L.D.	B.L.D.	-
	5	70.0	2.5	2.53	B.L.D.	B.L.D.	-
	10	-	2.8	2.53	B.L.D.	B.L.D.	-
	15	-	2.8	2.47	B.L.D.	B.L.D.	-
	20	-	2.5	2.53	B.L.D.	B.L.D.	-
	25	68.6	2.5	2.53	B.L.D.	B.L.D.	-
	30	68.6	2.5	2.53	B.L.D.	B.L.D.	-
	34	68.6	2.7	2.47	B.L.D.	B.L.D.	-
30 Sept 1974	1	71.4	2.5	3.09	B.L.D.	6.6	-
	5	71.4	2.5	3.01	B.L.D.	9.3	-
	10	-	2.7	3.09	B.L.D.	10.9	-
	15	61.6	2.5	2.81	B.L.D.	11.3	-
	20	70.0	2.5	2.95	B.L.D.	11.6	-
	25	68.6	2.5	2.87	B.L.D.	12.8	-
	30	68.6	2.5	3.04	2.3	7.4	-
	34	68.6	2.5	3.04	0.8	7.0	-
18 Nov 1974	1	-	-	-	5.3	12	-
	5	-	-	-	5.6	23	-
	10	-	-	-	2.8	93	-
	15	-	-	-	3.4	73	-
	20	-	-	-	14.6	44	-
	25	-	-	-	10.2	55	-
	30	-	-	-	6.5	65	-
	34	-	-	-	7.0	>93	-

APPENDIX F (Continued)

Date	Depth (m)	Nitrate-N (μg/l)	Nitrite-N (μg/l)	Reactive Silicate-Si (mg/l)	Phosphate-P (μg/l)	Total Phosphorus (μg/l)	Carbohydrate (as starch) (mg/l)
17 Feb 1975	1	72.8	2.8	-	8.1	-	-
	5	72.8	2.9	-	5.9	-	-
	10	72.8	2.8	-	5.9	-	-
	15	72.8	2.9	-	9.0	-	-
	20	72.8	2.9	-	9.0	-	-
	25	72.8	2.8	-	9.0	-	-
	30	72.8	2.7	-	-	-	-
	33	72.8	2.7	-	5.9	-	-
2 Mar 1975	1	72.2	2.9	-	-	-	-
	5	70.3	2.9	-	-	-	-
	10	72.1	2.9	-	-	-	-
	15	69.4	2.9	-	-	-	-
	20	69.4	3.2	-	-	-	-
	25	70.3	3.1	-	-	-	-
	30	69.4	3.1	-	-	-	-
	33	69.4	3.2	-	-	-	-

18 Mar 1975	1	-	2.9	-	14.6	-	-
	5	-	2.9	-	12.7	-	-
	10	-	2.9	-	9.6	-	-
	15	-	2.9	-	8.1	-	-
	20	-	2.9	-	1.2	-	-
	25	-	2.9	-	2.5	-	-
	30	-	2.9	-	9.9	-	-
	32	-	3.2	-	1.2	-	-
25 Mar 1975	1	-	-	-	5.0	-	21.9
	5	-	-	-	5.3	-	22.5
	10	-	-	-	5.3	-	22.4
	15	-	-	-	4.0	-	21.8
	20	-	-	-	5.0	-	20.2
	25	-	-	-	4.0	-	23.5
	30	-	-	-	3.7	-	22.4
	32	-	-	-	3.7	-	22.4
9 Apr 1975	1	-	3.4	-	4.0	-	19.2
	5	-	3.4	-	5.0	-	26.6
	10	-	3.6	-	4.3	-	24.0
	15	-	3.1	-	3.7	-	26.0
	20	-	3.1	-	3.1	-	27.3
	25	-	3.4	-	3.1	-	25.1
	30	-	2.5	-	2.5	-	24.1
	33	-	4.2	-	2.5	-	23.8

APPENDIX F (Continued)

Date	Depth (m)	Nitrate-N (µg/l)	Nitrite-N (µg/l)	Reactive Silicate-Si (mg/l)	Phosphate-P (µg/l)	Total Phosphorus (µg/l)	Carbohydrate (as starch) (mg/l)
30 Apr 1975	1	78.0	-	-	6.2	233	-
	5	78.4	-	-	6.2	245	-
	10	77.1	-	-	5.6	251	-
	15	77.6	-	-	3.4	229	-
	20	77.6	-	-	6.2	233	-
	25	77.1	-	-	0.6	236	-
	30	78.4	-	-	2.2	242	-
	33	78.4	-	-	1.2	245	-
13 May 1975	1	-	3.2	-	6.2	304	-
	5	-	3.2	-	5.3	313	-
	10	-	-	-	-	-	-
	15	-	3.2	-	6.2	310	-
	20	-	3.2	-	5.0	301	-
	25	-	3.5	-	3.7	295	-
	30	-	3.5	-	4.7	301	-
	33	-	3.5	-	5.0	319	-

6 June 1975	1	71.1	3.5	-	-	295	-
	5	74.5	3.5	-	-	273	-
	10	73.2	3.5	-	-	-	-
	15	72.0	3.5	-	-	279	-
	20	74.2	3.5	-	-	288	-
	25	73.6	3.5	-	-	288	-
	30	74.2	3.5	-	-	291	-
	33	73.2	3.5	-	-	304	-
25 June 1975	1	70.1	3.1	-	56	287	-
	5	72.5	3.1	-	56	285	-
	10	71.4	3.1	-	56	285	-
	15	71.4	3.1	-	59	285	-
	20	72.1	3.1	-	56	290	-
	25	70.1	3.1	-	56	283	-
	30	72.1	3.1	-	56	285	-
	33	72.1	3.1	-	56	285	-
16 July 1975	1	70.3	3.8	-	59	282	24.3
	5	70.7	3.8	-	59	285	23.2
	10	70.7	3.5	-	56	288	22.7
	15	72.7	3.5	-	56	282	-
	20	-	3.5	-	56	279	26.1
	25	70.7	3.5	-	56	277	-
	30	72.7	3.4	-	53	277	24.8
	33	72.0	3.5	-	56	277	26.4

APPENDIX F (Continued)

Date	Depth (m)	Nitrate-N (µg/l)	Nitrite-N (µg/l)	Reactive Silicate-Si (mg/l)	Phosphate-P (µg/l)	Total Phosphorus (µg/l)	Carbohydrate (as starch) (mg/l)
1 Aug 1975	1	73.1	3.4	-	54	-	-
	5	73.1	3.1	-	57	-	-
	10	73.8	3.1	-	60	-	-
	15	73.8	3.4	-	57	-	-
	20	73.1	3.4	-	60	-	-
	25	73.5	3.4	-	60	-	-
	30	73.5	3.4	-	54	-	-
	33	-	-	-	-	-	-
20 Aug 1975	1	72.9	2.9	-	50	271	24.5
	5	72.5	2.9	-	50	271	23.8
	10	72.5	2.9	-	47	277	-
	15	72.5	2.9	-	50	274	22.2
	20	72.9	2.9	-	53	274	24.7
	25	72.9	2.9	-	50	277	23.1
	30	72.9	2.9	-	47	271	25.1
	33	72.9	2.9	-	50	277	-

9 Sept 1975	1	71.7	2.9	-	56	268	-
	5	71.3	2.9	-	53	266	-
	10	71.0	2.9	-	50	268	-
	15	71.4	2.9	-	53	265	-
	20	71.0	2.9	-	50	268	-
	25	71.7	2.9	-	53	268	-
	30	70.6	2.9	-	50	265	-
	33	70.0	2.9	-	56	268	-
23 Sept 1975	1	74.3	3.2	-	56	-	-
	5	75.0	3.2	-	53	-	-
	10	73.6	3.2	-	56	-	-
	15	74.8	3.2	-	59	-	-
	20	76.6	3.2	-	56	-	-
	25	76.2	3.2	-	56	-	-
	30	75.9	3.2	-	56	-	-
	33	76.6	3.2	-	56	-	-
11 Oct 1975	1	76.3	3.5	-	59	-	-
	5	75.9	3.5	-	59	-	-
	10	75.6	3.5	-	56	-	-
	15	75.9	3.2	-	59	-	-
	20	76.3	3.2	-	59	-	-
	25	76.7	3.8	-	59	-	-
	30	76.3	3.8	-	59	-	-
	33	76.7	3.5	-	59	-	-

APPENDIX F (Continued)

Date	Depth (m)	Nitrate-N (µg/l)	Nitrite-N (µg/l)	Reactive Silicate-Si (mg/l)	Phosphate-P (µg/l)	Total Phosphorus (µg/l)	Carbohydrate (as starch) (mg/l)
27 Oct 1975	1	73.6	3.4	-	59	247	-
	5	74.6	3.4	-	59	247	-
	10	74.6	3.4	-	59	247	-
	15	74.3	3.4	-	59	249	-
	20	74.6	3.4	-	59	247	-
	25	-	3.4	-	59	253	-
	30	75.0	3.4	-	59	249	-
	33	75.0	3.4	-	59	249	-
5 Nov 1975	1	69.3	3.4	-	59	-	-
	3	69.7	3.4	-	59	-	-
	5	69.3	3.4	-	59	-	-
	10	69.7	3.4	-	59	-	-
	15	-	3.4	-	59	-	-
	20	69.3	3.4	-	59	-	-
	25	69.7	3.4	-	59	-	-
	30	69.7	3.4	-	59	-	-
	33	69.7	3.4	-	59	-	-

19 Nov 1975	1	68.9	3.2	-	56	255	-
	3	68.3	3.2	-	56	-	-
	5	-	3.2	-	56	255	-
	10	68.6	3.2	-	56	261	-
	15	68.6	3.2	-	56	261	-
	20	68.9	3.2	-	56	261	-
	25	68.9	3.2	-	56	257	-
	30	68.9	3.2	-	56	250	-
	33	68.6	3.2	-	59	255	-
10 Dec 1975	0	68.7	2.9	-	59	-	-
	3	69.0	2.9	-	59	-	-
	5	69.3	2.9	-	59	-	-
	10	69.0	2.9	-	59	-	-
	15	69.3	2.9	-	59	-	-
	20	69.3	2.9	-	59	-	-
	25	68.7	2.9	-	59	-	-
	30	68.0	2.9	-	59	-	-
	33	68.0	2.9	-	59	-	-
23 Dec 1975	0	69.4	3.1	-	59	-	-
	1	69.7	3.1	-	59	-	-
	5	70.4	3.1	-	59	-	-
	10	70.4	3.1	-	59	-	-
	15	70.1	3.1	-	59	-	-
	20	70.4	3.1	-	59	-	-
	25	70.1	3.1	-	59	-	-
	30	69.7	3.1	-	59	-	-
	33	70.1	3.1	-	59	-	-