A Summary of the 1992 Water Quality Objectives Monitoring Results at Tyhee Lake

INTRODUCTION

Water quality objectives are developed for specific bodies of water or water characteristics in the province, where they are or will be affected by mans activities. This is as a result of the Ministry of Environments mandate to manage water quality. These objectives have no legal standing, but are influential in determining effluent permit limits as well as indicating appropriate water uses.

The most prevalent problem associated with water quality in areas of development is the increased nutrient loading into the system (Boyd et al., 1984; Cooke et al., 1986). Higher levels of phosphorus and nitrogen are released into the water as a consequence of sewage disposal (septic tanks), road building, soil disturbance and vegetation removal (Boyd et al., 1984).

Increased nutrient levels can cause an increase in the growth of algae, decreasing water clarity and altering water chemistry. The limiting nutrient for algal growth in lakes is generally phosphorus. Phosphorus loading may cause algal blooms, and with the death of the algae, oxygen depletion in the lower depths of a water body occurs (Boyd et al., 1984; Mason, 1981; Loehr et al., 1980).

Tyhee Lake, located east of Smithers, B.C. (Figure 1), is a highly used and therefore, possibly a impacted lake. In 1984, water quality objectives were prepared for this and three other

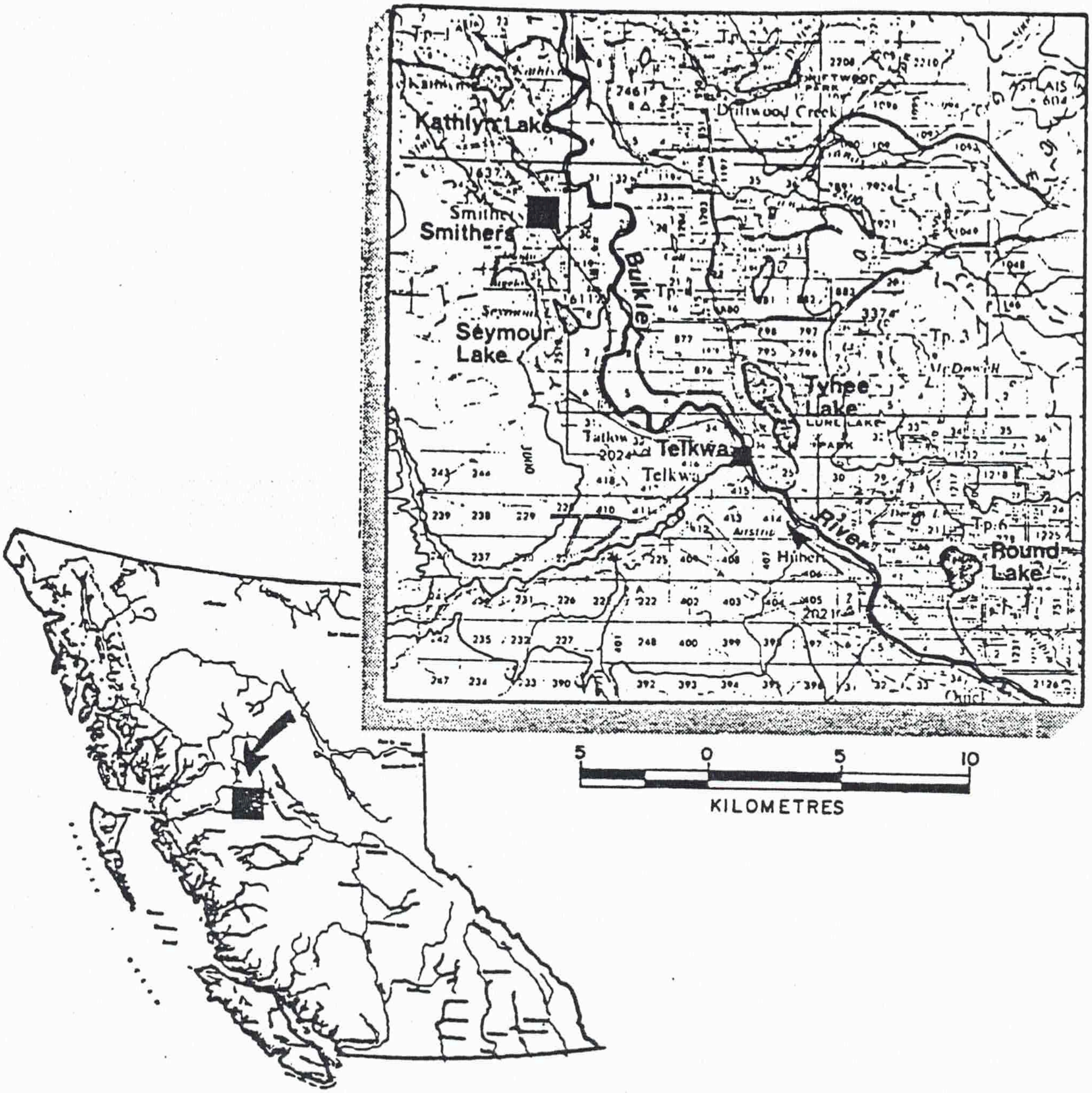


FIGURE 1: LOCATIN OF KATHLYN, SEYMOUR, ROUND AND TYHEE LAKES

lakes in the Smithers region (Kathlyn, Round and Seymour lakes), in response to requests from the Planning Department of the Regional District of Bulkley-Nechako (Table 1). The initial sampling for the report was carried out in 1982, and since the release of the objectives document, yearly water quality objectives monitoring has been performed.

A summary report is prepared by the Ministry of Environment each year to determine if the water quality objectives have been met. The purpose of this report is to analyze the 1992 sampling results for Tyhee Lake, determine the impacts on the lake, and the possible steps that could be taken to control the eutrophication and ensure limited protection of the lake habitat and ecology.

Tyhee Lake has a relatively low flushing rate, exhibiting an average of approximately 0.2 lake volumes/yr. This indicates that water exchange occurs once every five years or longer. The total volume, estimated runoff, water retention time and morphometric data are summarized in Table 2. The bathymetry of the lake (Figure 2), shows the deepest point to be approximately 20 meters. This is the deep sampling point for the objectives monitoring.

TABLE 1

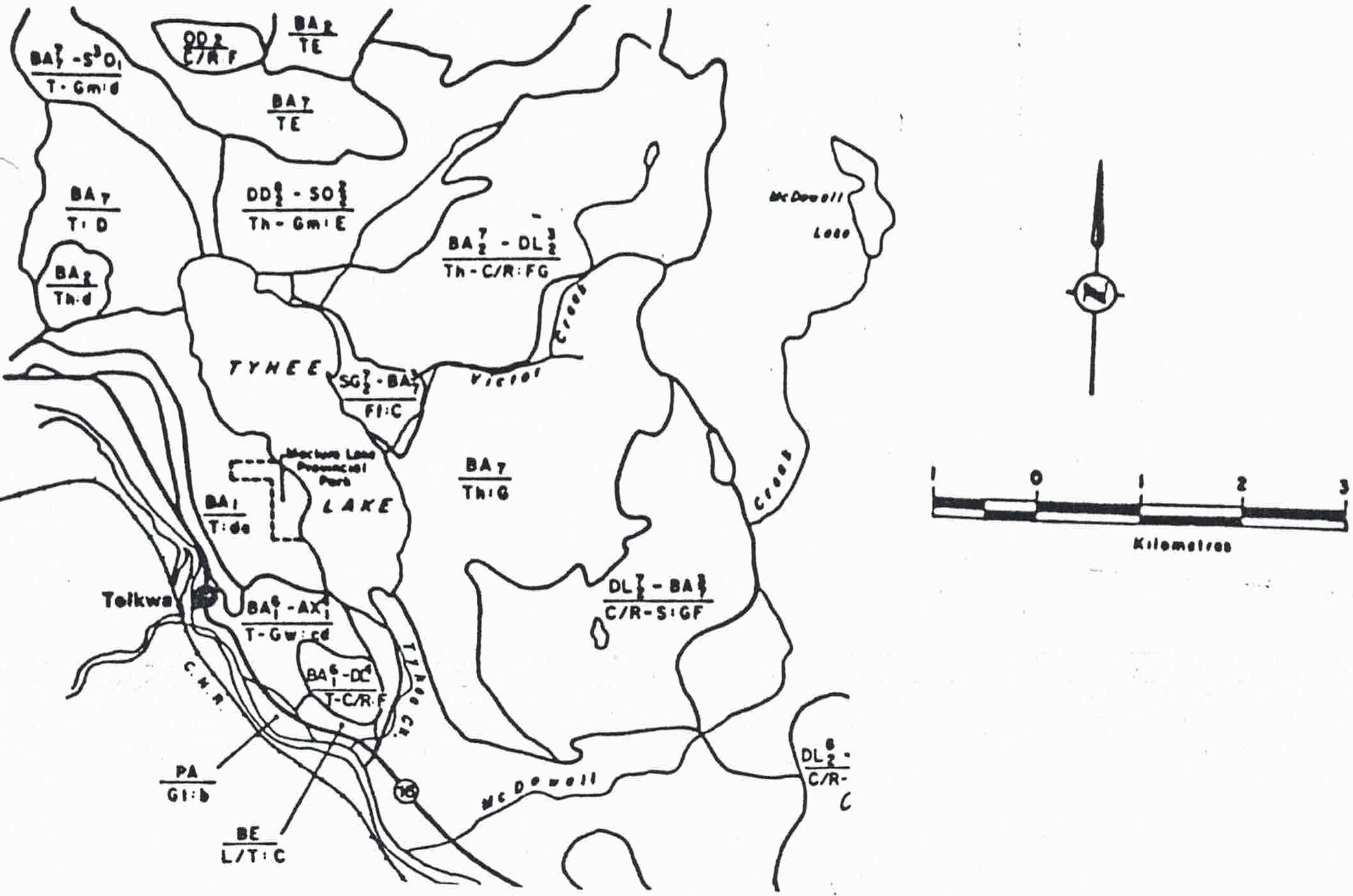
SUMMARY OF PROVISIONAL WATER QUALITY OBJECTIVES
FOR KATHLYN, SEYMOUR, ROUND AND TYHEE LAKES

Designated Water Uses	- domestic, industrial and irrigation water supply - water contact recreation, aquatic life:
Fecal Coliform Bacteria	- the fecal coliform density shall not exceed 10 MPN per 100 mL in 90 percent of lake water samples taken in any consecutive 30-day period. This objective applies only to grab samples taken near or in a domestic intake. - at beaches the fecal coliform density shall not exceed a running log mean of 200 MPN/100 mL, calculated from at least 5 weekly samples taken during the recreation season, nor shall more than 10 percent of samples during any 30-day period exceed 400 MPN/100 mL.
Nutrients (long term objective)	- total phosphorus concentration at spring overturn shall not exceed 0.015 mg/L. This objective applies to the average of three samples taken 1 m below the surface, at mid depth and 1 m above the bottom, all at about mid-lake. Not applicable to Seymour Lake (see text).
Turbidity (long term objective)	- the turbidity shall not exceed 5 NTU in any grab sample taken near or in a domestic intake, nor shall the average of at least 10 such samples taken throughout the year exceed 1 NTU.
Colour (long term objective)	- the colour shall not exceed 15 TCU in any grab sample taken at any time from near or in a domestic intake. Not applicable to Seymour Lake (see text).

(1984 REPORT)

Table 2
Summary Data for Tyhee Lake: Morphometric, Water Retention and Flushing Rate

Attribute		Value
Elevation (m)		549
Surface area (ha)		318
Volume (dam3)		35278
Mean depth (m)		11.1
Maximum depth (m)		22.2
Perimeter (m)		9754
Water retention time	Max.	16.6
(yr)	Min.	2.94
	Mean	5
Flushing rate/year	Max	0.3
	Min.	0.06
	Mean	0.2



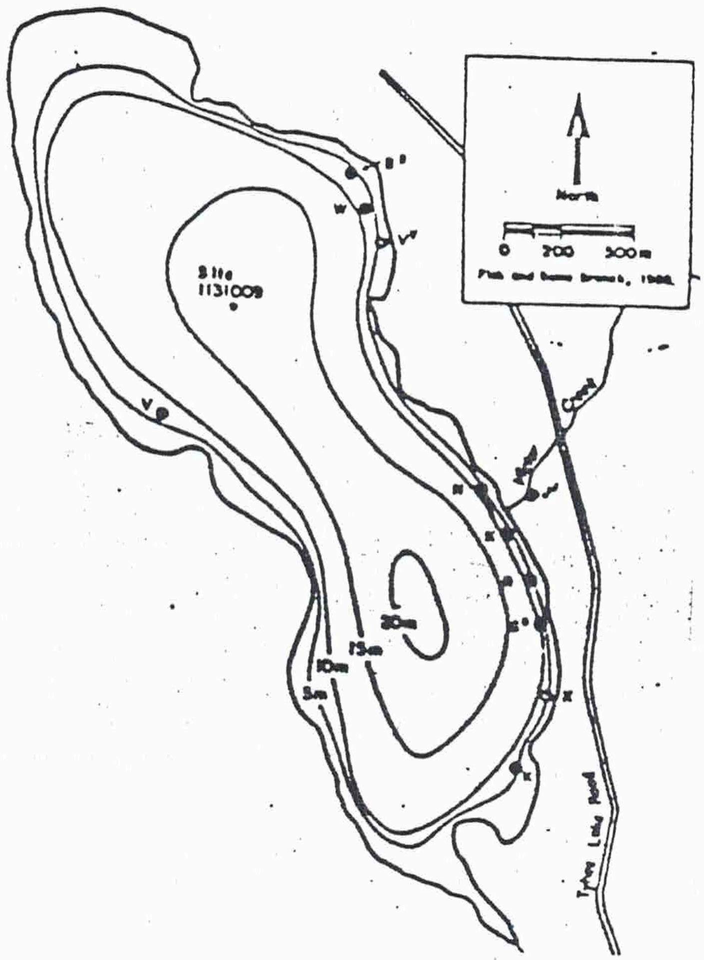


Figure 2. Soil types and bathymetry of Tyhee Lake.

The watershed has a diverse range of soil conditions although the majority were found to be good for phosphorus absorption. This is an important attribute when determining the suitability of soils for waste disposal systems and protecting against seepage of wastes into the lake (Figure 2).

Water Use

The lake is an important recreational area, with public beaches and a provincial campground. Water-contact sports are of great importance at this lake. Sport fishing for burbot, pygmy whitefish, rainbow and cutthroat trout also occurs at the lake although the fishing pressure is light (Boyd et al., 1984).

The water is also used for both domestic and industrial water supply, and an irrigation water supply. Tyhee Lake has twelve domestic water licences, three waterworks licenses (50 m^3/day), and one industrial license (27 m^3/day for a trailer park) (Table 3).

Water Quality

Tyhee lake is dimictic. The spring overturn occurs in late April or early May and the fall overturn around late October. The oxygen level always remains high at the surface. At depth, anoxic conditions generally persist except immediately after the overturn when the water column is highly mixed. Previous studies have found the hardness and alkalinity of the lake to be quite

Table 3
Water Licences on Tyhee Lake*

Priority Date	License Number	Point of Diversion	Volume	Use	Location	License
1972-03-25	C 9855	K	2.3 m3/d	DOM	L 2 of L 252 R 5 Coast Dist Plan 5949	Lowe, Ronald and Elaine
1972-04-13	C407588	N	2.3 m3/d	DOM	L 3 of L 252 R 5 Coast Dist Plan 5949	Murdoch, Gary and Elizabeth
1972-05-03	C 51653	BB	27 m3/d	WWK	L 1-12 Incl of L 794 R 5 Coast Dist Plan 6345	Hidber, J.A. and Louise
1972-07-11	C 62308	V	27 m3/d	ENTPR	L 1 of Sect 2 TP 4 R 5 Coast Dist Plan 10278	Beaubien, Raymond and Vera
1973-11-05	C 43095	R	2.3m3/d	DOM	L 1 of L 252 R 5 Coast Dist Plan 5949	Currie, Gail and Robert
1974-06-28	C 45178		2.3m3/d	DOM	L 3 of L 794 R 5 Coast Dist Plan 7352	Lovatt, Susan
1978-07-31	C 53281	GG	2.3m3/d	DOM	L 5 of Sect 36 TP 5 R 5 Coast Dist Plan 8647	Burger, R. and Carol
1979-09-28	C 54595	K	2.3m3/d	DOM	L 7 of of Sect 36 TP 5 R 5 Coast Dist Plan 5233	Sandberg, Sally A.
1981-04-30	C 57743	JJ	2.3m3/d	DOM	L 5 of L 794 R 5 Coast Dist Plan 7352	Cambell, Joan J.
1981-06-15	C 57742		2.3m3/d	DOM	L 1 of Sect 36 TP 5 R 5 Coast Dist Plan 8647	Barklay, Ada M.
1983-07-06	C 60201		2.3m3/d	DOM	L 3 of L 2 TP 4 R 5 Coast Dist Plan 10278	Jackson, Frederic
1983-07-06	C 60202		2.3m3/d	DOM	L 2 of Sect 2 TP 4 R 5 Coast Dist Plan 10278	Blackburn, Robert
1985-05-13	C 62004		2.3m3/d	DOM	L 879 R 5 Coast Dist	Blunt Creek Sawmill Limited
1989-01-24	C 72046		2.3m3/d	DOM	L 4 of Sect 36 TP 5 R 5 Coast Dist	Koopmans, Albert and Evelyn
1990-07-06	C 72079		2.3m3/d	DOM	L 3 of Sect 36 TWP 4 R 5 Coast Dist Plan 8647	Bakker, John and Irene

*From Water Management Files, Ministry of the Environment high because of the deep glacial soils and low flushing rate. As a result, the buffering capacity of the lake water is correspondingly high. The same study also found the lake to be eutrophic, due to the high levels of phosphorus contributed from the lake sediments (Boyd et al., 1984).

METHODS

The 1992 water quality objectives monitoring for Tyhee Lake began on March 4, 1992. Sampling was performed through the lake ice until melting in April. From this time to the end of the sampling period, a boat was used to reach the site. The sampling site, is located in the deepest part of the lake (Figure 2). E216924 is the site number given to this sample location as a means of identification on the Ministry of Environment's computerized data storage system, SEAM.

An eight litre Van Dorn bottle was utilized to retrieve samples from the water column for ion analysis. A lake profile for temperature, dissolved oxygen, conductivity and redox potential was obtained with a hydrolab. This instrument was calibrated using the Winkler method for oxygen determination (HACH kit) at the surface and checked again at the bottom. Later in the sampling period (August), a YSI dissolved oxygen meter replaced the HACH kit for calibration purposes.

Two hundred millilitres of samples taken from specific water depths (0, 3 and 6m) were filtered and frozen for chlorophyll-a analysis.

Phytoplankton samples were taken at the same three depths and fixed with Lugol's solution. Zooplankton hauls were performed from the bottom to the surface using a zooplankton net, and fixed with Red Bengal and Formalin. With each haul, the net was rinsed with deionized water to remove all zooplankton.

Tap water samples were taken from three sites around the lake for analysis of faecal coliforms, true colour and turbidity. A specially treated bottle was used for the bacteriological sampling. The three stations: E207559 (station 1), E207560 (station 2) and E207561 (station 3) are marked on Figure 2. This sampling was carried out for a total of five times in thirty days, between June 15 and August 10, 1992.

Data collection at the deep site was performed by personnel of the Waste Management Branch in Smithers, B.C.. A representative of the Tyhee Lake Preservation Society (T.L.P.S.) carried out the tap sampling around the lake.

Secchi depths were taken using standard secchi disks. At the deep site, Ministry personnel determined the depth on each sampling day. A number of points around the lake were monitored daily by members of the T.L.P.S.

Dr. Pat Warrington from the Water Quality Branch in Victoria visited the Lake on July 15, 1992. He performed a brief survey of the aquatic weed populations along the shallows of the lake. All chemical and biological analyses were performed by Zenon Environmental Laboratories located in Burnaby, B.C. The collected chemical data is stored on the Ministry environmental database, SEAM.

WATER QUALITY RESULTS

The graphs of temperature in Spring and Summer indicate that spring turnover of the water occurred around the end of April, or beginning of May (Figures 3 and 4), when the temperature throughout the water column was nearly consistent. With the onset of summer, the thermocline developed again to become most steep in late July (noted July 28th). This thermal stratification prohibits significant mixing between the hypolimnion and epilimnion. With Fall cooling, the water again becomes nearly isothermal, allowing for a second turnover in November (Figure 4).

Figure 5 illustrates the typical progression of dissolved oxygen in the lake. Before the spring overturn, the oxygen is depleted at depth. When the mixing occurs in early May, the bottom waters become oxygenated. With the advancement of summer, strong thermal stratification develops, and the dissolved oxygen at depth can not be renewed with the highly oxygenated epilimnetic water. Low oxygen or anoxic waters result in the hypolimnion as the oxygen is consumed in biological processes (e.g. respiration, decomposition).

The Hydrolab used for the lake profiles becomes less accurate with lower levels of oxygen, therefore the concentrations indicated in the lower depths may be inaccurate. The YSI dissolved oxygen meter,

Figure 3.
Temperature Profile for Tyhee Lake, 1992:
Spring Runoff

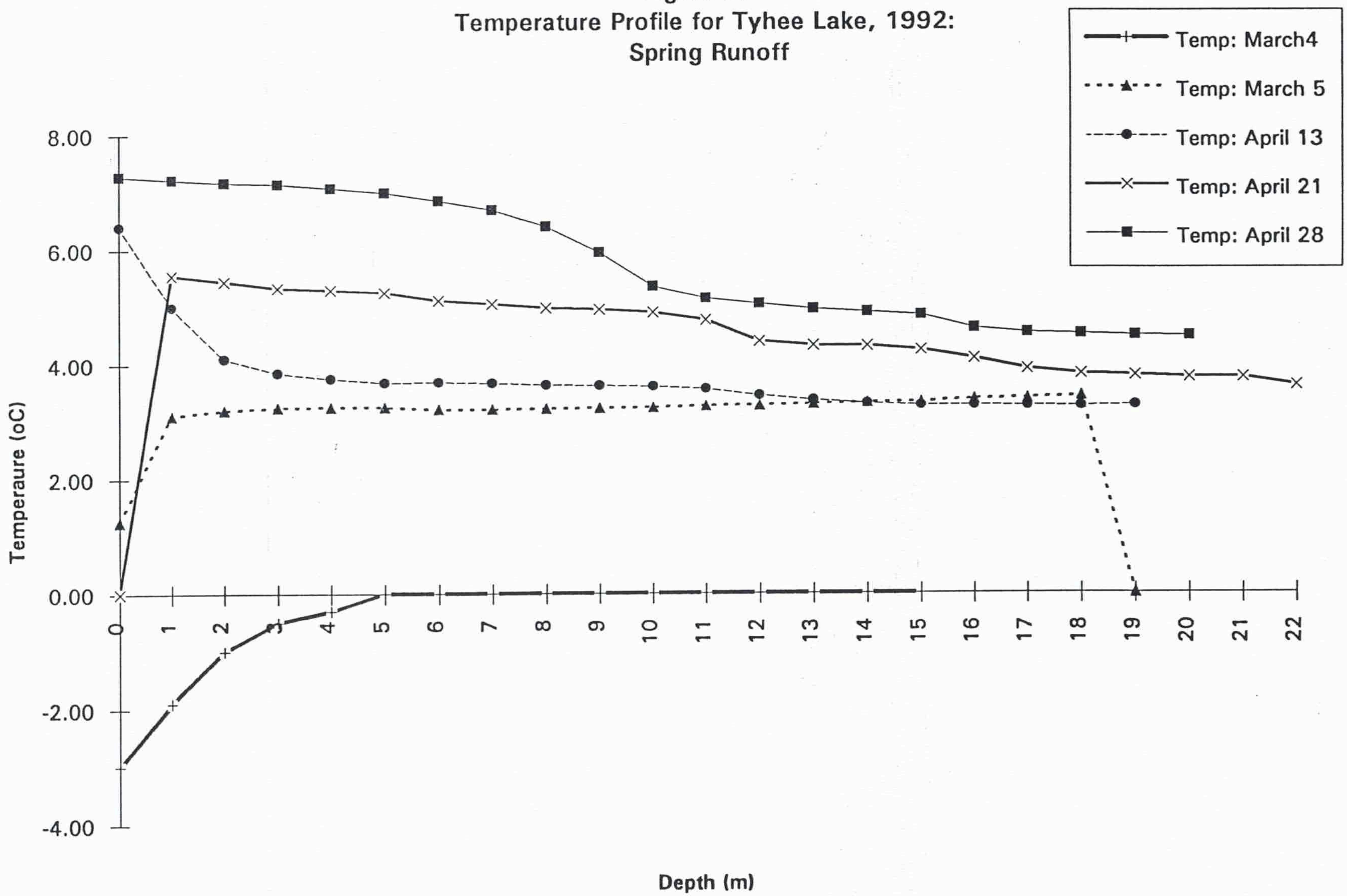
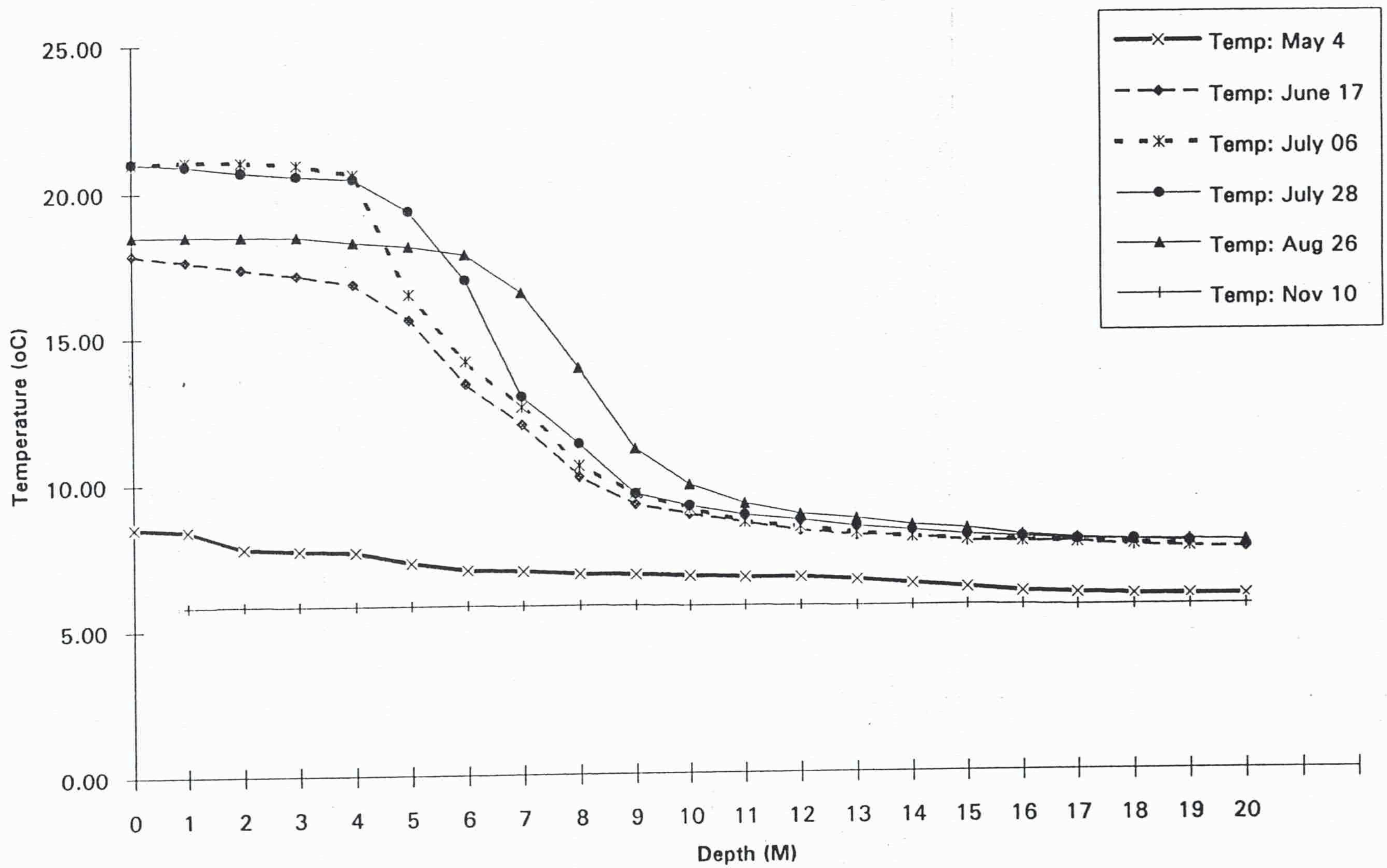


Figure 4.
Temperature Profile for Thyee Lake, 1992:
May to November



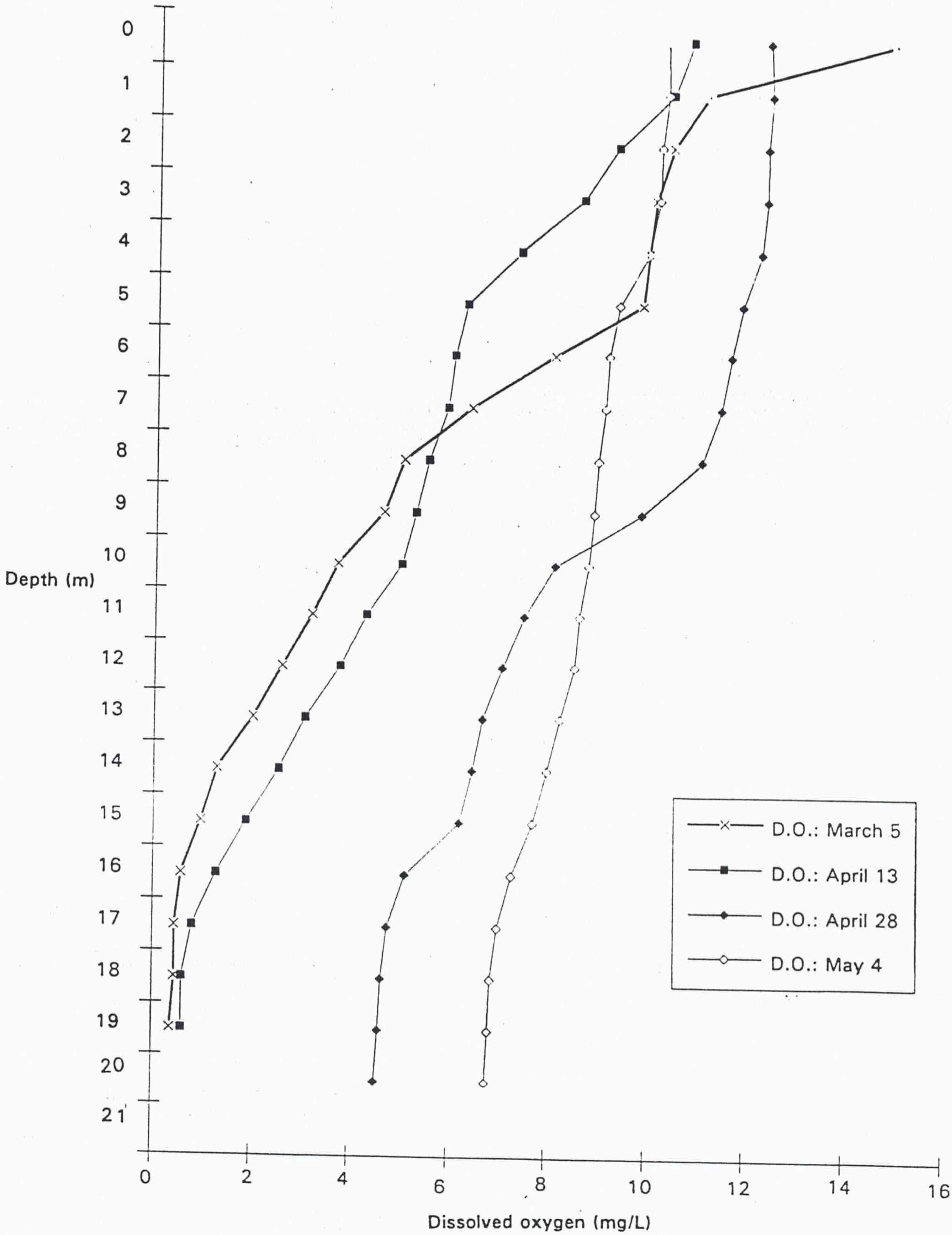


Fig. 5. Dissolved Oxygen for Thyee Lake, 1992

a more reliable instrument for measuring low oxygen concentrations, indicated no oxygen in the bottom 2 m of the lake. In general, the dissolved oxygen and redox potential exhibit conditions typical of lakes with internal loading (Table 4) (Nordin, 1992). The oxygen drops to zero and the redox becomes negative at depth over the course of the summer. These values are coincident with an increase in the phosphorus, giving further evidence to the high contribution of the sediments to the nutrient loading problem. Even during the spring when thorough mixing is expected to occur, the oxygen concentration in the deep water is less than that in the surface water. This is an indication that the lake does not exhibit a full turn over, which may be particularly significant to nutrient recycling. Without total destratification, the hypolimnetic oxygen depletion happens more quickly and persists for a longer period (Nordin, 1992; Boyd et al., 1984). As a result, conditions near the lake bottom allow phosphorus to move from the sediments into the water column. There is increased possibility for more severe algal problems than would otherwise be evident if full turnover was available (Nordin, 1992). The levels of phosphorus observed in the lake over the six month sampling period are higher than the recommended level of 0.015 mg/L at spring overturn (listed in the objectives report, Table 2 and Table 5). Figure 6 shows the mixed waters during the spring overturn have phosphorus concentrations above 0.02 mg/L with a maximum of 0.064 mg/L at 20 m, probably as a result of the phosphorus entering solution from the sediments. As the summer progresses, the phosphorus concentration at 16 m steadily increases. As the strong thermocline in July inhibits the mixing of the upper and lower

Table 4
Dissolved Oxygen and Redox potential at Tyhee Lake
over Depth: March to November 1992
Station E216924

		Depth (m)				
Date	Parameter	0	5	10	15	Bottom
5-Mar	Dissolved Oxygen (mg\L)	14.90	9.85	3.71	0.97	0.38
	Redox Potential	0.117	0.155	0.178	0.186	0.183
13-Apr	Dissolved Oxygen (mg\L)	10.83	6.29	5.00	1.88	0.60
	Redox Potential	0.323	0.354	0.366	0.375	0.379
28-Apr	Dissolved Oxygen (mg\L)	12.38	11.88	8.12	6.20	4.54
	Redox Potential	0.309	0.313	0.332	0.342	0.350
17-Jun	Dissolved Oxygen (mg\L)	8.94	8.94	5.56	3.97	2.86
	Redox Potential	0.224	0.235	0.269	0.282	0.288
28-Jul	Dissolved Oxygen (mg\L)	9.07	9.10	2.30	1.88	1.88
	Redox Potential	0.209	0.222	0.266	0.265	-0.091
26-Aug	Dissolved Oxygen (mg\L)	9.20	9.17	2.26	1.98	1.92
	Redox Potential	0.199	0.205	0.241	0.026	-0.112
10-Nov	Dissolved Oxygen (mg\L)	11.22	11.28	11.40	11.50	11.57
	Redox Potential	0.240	0.245	0.252	0.259	0.263

TABLE 5.
Total Phosphorus in Tyhee Lake: 1992 Data mg\L
Station E216924

	Date (Yr/Mo/Day)						
	92/03/04	92/04/21	92/05/05	92/06/17	92/07/06	92/07/28	92/08/26
Depth (m)							
0-0.	0.022	0.033	0.021	0.01	0.012	0.011	0.008
4		0.037	0.031				
8	0.031	0.029	0.028	0.011	0.017	0.013	0.015
12		0.038	0.025				
16	0.072	0.041	0.025	0.041	0.077	0.097	0.114
20		0.064	0.029				

TABLE 6.
Total Phosphorus Levels at Spring Overturn mg/L*
in Tyhee Lake Station E216924

	Depth (m)		
Year	0-5	6-13	14-20
1985	0.053	no value	0.052
1986	0.035	no value	0.072
1987	no value	no value	no value
1988	0.028	0.031	0.027
1989	0.018	0.04	0.074
1990	0.019	0.027	0.081
1991	0.08	0.027	0.08
1992	0.035	0.0335	0.0525

* for date and exact depths see Appendix 1

TABLE 7.
1992 Phosphorus to Nitrogen Ratio (total)
for Tyhee Lake Station E216924

	Depth (m)		
Date (Yr/Mo/Day)	0-0.5	8	16
92/03/04	0.022P; 0.62N 1 : 28.18	0.031P; 0.57N 1 : 18.39	0.072P; 0.93N 1 : 12.92
92/06/17	0.01P; 0.6N 1 : 60	0.011P; 0.57N 1 : 51.82	0.041P; 0.74N 1 : 18.05
92/07/06	0.012P; 0.6N 1 : 50	0.017P; 0.58N 1 : 34.12	0.077P; 0.85N 1 : 11.04
92/07/28	0.011P; 0.7N 1 : 63.64	0.013P; 0.63N 1 : 48.46	0.097P; 0.97N 1 : 10
92/08/26	0.008P; .055N 1 : 68.75	0.015P; 0.63N 1 : 42	0.114P; 1.01N 1 : 8.86

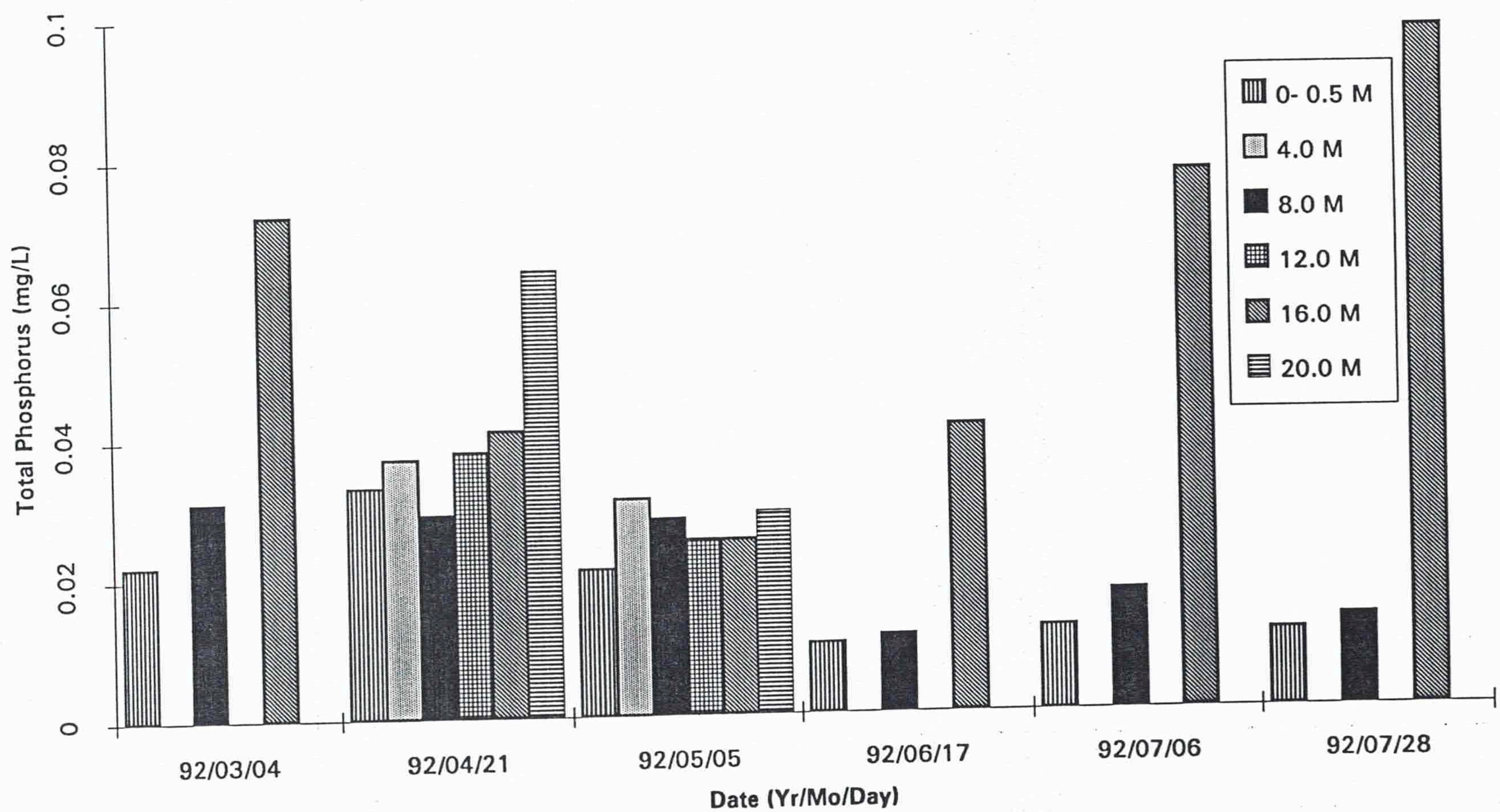


Figure 6. 1992 total phosphorus at 6 depths of Tyhee Lake

waters, these high levels indicate the majority of loading is probably occurring below the thermocline.
At the spring turnover the phosphorus levels are high throughout the water column (Figure 6). In four of the six years of data collection, a strong gradient in phosphorus concentration is evident from the surface to bottom, another indication of incomplete mixing (Table 6).

When the ratio of phosphorus to nitrogen is reviewed, it is evident that phosphorus is the limiting nutrient (Table 7). The concentrations of nitrogen compounds do not significantly change over the sampling period (Table 8). This indicates that the clean-up efforts are presently headed in the right direction: the control of phosphorus loading.

The amount of phosphorus loading has a direct effect on the organisms within the lake. The biology of the lake is important for the process of assessing eutrophication. The dominant phytoplankton in the lake are diatoms and green algae, not the blue-green algae that are present in most eutrophic lakes (Nordin, 1992; Mason, 1981) (Table 9). The number of cells per litre is lower than that expected in a eutrophic lake (Nordin, 1992). There are high concentrations of zooplankton in the lake, the most abundant being Daphnia sp., which is viewed to be an ideal organism for grazing on algal material (Table 10) (Nordin, 1992). It is possible that the phytoplankton populations are being kept low due

Table 8.
1992 Nitrogen Concentrations in Thyee Lake
Station E216924

Date (Yr/Mo/Day)	Depth (M)	N.Kjel:T mg/L	NO2NO3:D mg/L	Nitrit:D mg/L
92/03/04	0.5	0.62		
	16	0.93		
	8	0.57		
92/06/17	0	0.6	<0.02	<0.005
	8	0.57	0.05	<0.005
	16	0.74	0.07	0.005
92/07/06	0	0.6	<0.02	<0.005
	8	0.58	<0.02	<0.005
	16	0.85	0.11	0.013
92/07/28	0	0.7	<0.02	<0.005
	8	0.63	<0.02	<0.005
	16	0.97	0.07	0.029
92/08/26	0	0.55	<0.02	<0.005
	8	0.63	<0.02	<0.005
	16	1.01	<0.02	<0.005

Table 9.
1992 Dominant Phytoplankton and Concentration at Three Depths
Tyhee Lake Station E216924

Date (Yr/Mo/Day)	Order	Species	# cells \mL at each depth		
			0 M	3 M	6M
92/04/13	Centrales	*Stephanodiscus astraea var. menutula*	2142	2820	10674
92/07/06	Chlorococcales	*Crucigenia rectangularis*	61.6	100.8	non-dominant
		sphaerocystis schroeteri	89.6	non-dominant	136.8
	Cryptomonodales	*Chroomonas acuta*	57.4	243.6	285
	Tetrasporales	*Gloeocystis ampla*	33.6	89.6	non-dominant
92/06/17	Chroococcales	*Anacystis delicatissima*	622	1913	5355
	Cryptomonodales	*Chroomonas acuta*	260	non-dominant	non-dominant
		Cryptomonus ovata	130	non-dominant	non-dominant
92/07/28	Nostacales	*Anabaena flos-aquae*	2578	1012	93.5
	Chlorococcales	*Botryococcus braunii*	non-dominant	204	non-dominant
	Cryptomonodales	*Chroomonas acuta*	non-dominant	296	255
92/08/26	Cryptomonodales	*Chroomonas acuta*	134	285	251
	Nostacales	*Anabaena flos-aquae*	84	non-dominant	non-dominant
	Chroococcales	*Anacystis elachista*	392	non-dominant	1140
		Anacysta limneticus	89.6	non-dominant	274
	Chlorococcales	*Botryococcus braunii*	non-dominant	68.4	non-dominant

Table 10.
1992 Dominant Zooplankton Species in Tyhee Lake
Station E216924

Date	Phylum	Order	Species	#organisms/Total Sample Replicate 1	Replicate 2
April14\92		Cyclopoida	*Diacyclops Bicuspidatus thomasi* : adult	13965	8118
			: copepodite	5320	4653
June 17\92		Cladocera	*Daphnia pulex*	25323	18550
		Cyclopoida	*Diacyclops Bicuspidatus thomasi* : adult	20687	18725
			: copepodite	18548	12250
	Rotifera	Ploima	*Kellicottia longispina*	10878	7700
			Asplancha	22827	18725

to high grazing pressure from the zooplankton. In response to low concentrations of phytoplankton and high nutrients in the spring, the opportunity arose for larger non attached algae to proliferate in the lake. This is the source of complaints from residence around the lake and its decay at depth adds to the depletion of the oxygen.

Warrington (1992) stated that there is a persistent algal problem at Tyhee Lake, with the dominant species changing from rooted species to forms that float in the water column. This is a good indication that the nutrients, especially phosphorus, are now dissolved in the water column instead of being retrieved primarily from the sediments.

By reviewing other characteristics of the water column, further evidence as to the quality of the water can be inferred. The objectives report listed that the faecal coliform bacteria shall not exceed 10 MPN per 100 ml in 90 % of the water samples over the 30 day period. Our results for Tyhee Lake show that the objective was met with most samples giving values below 2 (Table 11). This indicates that septic tank seepage may not cause significant nutrient loading. The turbidity and colour both met the objectives requirements of not exceeding 5 nephelometric turbidity units (NTU) and 15 true colour units (TCU) respectively. As colour is representative of the concentration of phytoplankton in the water, it is not unexpected to see low TCU (Boyd et al., 1984). The chlorophyll-a values are also correlated to the phytoplankton concentration and are another method of

Table 11.
1992 Water Quality Objectives Domestic Sampling
Three Stations on Tyhee Lake

Station	Variable	Units	Date (Yr/Mo/Day)				
			92/07/15	92/07/20	92/07/27	92/08/04	92/08/10
Station 1 E207559	Fecal Col	CFU	< 2	18	< 2	< 2	
Station 2 E207560	Fecal Col	CFU	< 2	2	< 2	< 2	<2
	Colour-T	Col Unit	10	5	8		10
	Turbidity	NTU	0.9	0.4	0.6		0.5
Station 3 E207561	Fecal Col	CFU	< 2	< 2	< 2	<2	<2
	Colour-T	Col Unit	10	7	10	5	5
	Turbidity	NTU	0.6	0.4	0.6	0.2	1.5

determining eutrophication of a lake (Wetzel, 1975). But again, possibly as a result of the high grazing pressure of the zooplankton, the values are low (Table 12).

CONCLUSIONS AND SUGGESTIONS

The results of the 1992 Water Quality Objectives Monitoring indicate that the lake is subject to nutrient loading. It seems that the high concentrations of phosphorus within the sediments are now moving into the water column and causing eutrophication. Thus, this would indicate internal loading of nutrients is the most significant factor when discussing eutrophication in Tyhee Lake (Nordin, 1992). Sources indicate that even when phosphorus loading from the external environment is decreased to negligible levels, continued algal blooms will persist, due to a slow flushing rate, and high levels of nutrients being resuspended from the sediments (Cooke et al., 1986). One previously suggested method to deal with this problem is hypolimnetic aeration (Boyd et al., 1984; Beatty-Spence, 1990; Nordin, 1992). This method would allow for the retention of the stratification within the lake, but add additional dissolved oxygen to the hypolimnion (Nordin, 1992; Beatty-Spence, 1990). The result would be less resuspension of phosphorus from the sediments and thus less nutrient loading. With less nutrient loading to the water column, a decrease in the algal population would be expected. Because this method is expensive and difficult to do, it is only recommended if retention of stratification is important (i.e. cold water fisheries) (Nordin, 1992).

TABLE 12.
1992 Tyhee Lake Chlorophyll -a Data
Site E216924

	Date (Yr/Mo/Day)				
	92/04/13	92/06/17	92/07/06	9	92/08/26
Depth (m)					
0.0	6.7	3.5	1.6	#	3.8
0.0	6.9	4.3	1.4	#	4.1
3.0	16.9	4.1	1.8	#	4.8
3.0	17.6	4.0	2.0	#	7.0
6.0	11.5	5.6	2.1	#	7.6
6.0	11.9	5.9	4.3	#	5.4

If retaining stratification within the lake is not an important factor, the less expensive, more feasible method of destratification may be utilized. The result would be the oxygenation of the deep water by a mixing process. As stated earlier, this is dependant on the need for temperature stratification by fish stocks.

FURTHER TESTING AND ANALYSES

All of the Water Quality Objectives Monitoring results concerning Tyhee Lake have not been returned from the laboratories to the Ministry of Environment at this time. The majority of zooplankton hauls and some phytoplankton grabs have not yet been analyzed as well as the last sampling days data for the deep site. Until the results of this data are collected and assessed, a complete review can not be carried out. A comparison of this and previous years results will also be performed to further understand the direction and changes in the water quality of Tyhee Lake.

The external sources of nutrients have not been studied for the Tyhee Lake drainage basin. Although the 1992 results indicate internal loading is the major contributor to the eutrophication process, it is important to have knowledge and understanding of the external influences to the system. Presently, their relative importance to the eutrophication of the lake is not documented. No valid stream studies have been performed to determine the proportion of nutrients entering the lake through surface runoff. There are two important factors involved with this external loading monitoring. First, the inflow streams are intermittent, carrying high volumes of water in spring but becoming negligible or dry by late summer. Previously, a small number of grab samples were taken from inflowing streams and the phosphorus content was measured. It was noted the concentration varied but no estimate of flow was determined, and as a result, the impacts could not be evaluated. Second, the terrain around Tyhee Lake causes a large amount of the spring water runoff to drain down the hill sides, straight into the lake without entering via a stream. This non point inflow of surface water can not be monitored accurately.

Further testing should be planned for the following spring, with a determination of inflow and outflow rates in streams to and from the lake to better ascertain the sources and relative amounts of nutrient loading. Cooke et al. (1986) indicated it is best to measure phosphorus loading during high discharge periods such as snowmelt or high rains. This is important in order that the loading is not underestimated. Point sources like urban storm drains can be significant for the phosphorus budget in a lake (Cooke et al., 1986). When this discharge occurs, it is generally large and of poor water quality.

In streams where nutrient loading is suspected, upstream and downstream nutrient contents and flow rates should be monitored in order to locate the source. Once a source is determined, methods for decreasing the nutrient loading into the lake from that source can be developed.

In connection with this work, the Water Management Branch in Smithers have monitored the inlet streams and the outlet of the lake for both depth ad flow rates throughout the 1992 ice free season. Similarly, the lake level has also been observed. From the data collected, a new estimation of flushing rate and lake turnover can be calculated. The intermittence of inflow streams will be documented, thus helping to determine if the inflow of external nutrients is from a non point source as suspected (Marquis, 1992). Once these results are obtained, they can be incorporated into the water quality management plan.

A fluorometer has recently been purchased by the Ministry of Environment in Kamloops. The instrument will be used in the lake to determine if septic tank seepage is occurring and the relative importance of it as a source of nutrients. This sampling method was tried in 1982, but due to a technical failure, no results were obtained for Tyhee Lake.

The suggestions listed previously for controlling eutrophication in the lake are dependent on fish stocks within the lake. These stocks therefore must also be taken into account. As well as a large number of coarse fish being present, the Fisheries Branch in Smithers have been stocking the lake with trout. A gill netting was performed in November of 1992 and estimates of populations were recorded. The results should be reviewed with respect to the effects of destratification on fish stocks. The number of zooplanktivorous fish is also an important factor to note in order to understand the high concentrations of zooplankton within Tyhee Lake (Nordin, 1992).

A new species of fish was discovered in Tyhee lake in 1992. The Giant Pigmy Whitefish is a species present only in two lakes in British Columbia (Hatlevik, 1992). This recent discovery may also play an important role in the management of Tyhee Lake and should be reviewed further.

Before full conclusions can be developed, a decision must be reached as to the goals of the lake water management. Is the aesthetic value of the lake (i.e. clarity) more important than the fish stocks? Or is the most important issue recreational use, therefore making faecal coliform counts and large weeds the priority? Are the large numbers of waterfowl using the lake important? Their ideal habitat is within the weeds. These types of questions must be addressed in order to come up with a viable plan of action.

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MINISTRY OF ENVIRONMENT
NOV 19 1992
ENVIRONMENTAL
PROTECTION BRANCH
SMITHERS, B.C.

16 November 1992

Deborah Portman
Environmental Assessment Section
Environmental Protection Program
Bag 5000
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I have quickly reviewed the data you sent and the data that are stored on SEAM for Tyhee Lake in the time that I made for this. I should make some comments on the data before saying anything about the interpretation and what conclusions that might be drawn from them.

It would appear that there are some problems with some of the field data. There should be at minimum some calibration data for all of the profiles and preferably some QA/QC. For instance, for redox on March 5th, the range is 117-187 mV which is, in absolute terms, very low and out of character for the dates which follow (300-400 mV). There is also a significant increase in conductance between May 4 and June 17 which seems most implausible. The temperature in the figure of profiles for March 4 must be an error (the raw data is not given in the prior tables).

In examining the data, one of the characteristics of the lake appears to be that it does not appear to be mixed very well (if at all) either in the spring or in the autumn. It is particularly noticeable in the spring and may be of particular significance in the recycling of nutrients. If the lake does not completely destratify and the whole lake does not come to a full level of saturation, the ensuing hypolimnetic oxygen depletion happens more quickly and persists for a longer period, which provides the conditions for movement of phosphorus from the sediments into the water column and thus for the summer algal problems to be much more severe than would otherwise be if the lake were able to take a "full breath" before the onset of summer stratification and hypolimnetic oxygen depletion. The data in Table 8 are fairly convincing that at least 4 of the 6 show a strong gradient with depth.

noxia

The D.O. and redox data in general seem to show that the conditions in the late summer are quite typical of lakes that have substantive internal loading. The D.O. drops to zero and the redox is negative in the deepest waters in summer which is coincident with increasing phosphorus. The release mechanism does not appear to be related to the iron/sulfur cycle as there is no apparent increase in iron concentration. It would also be the case that any effort in controlling nutrients be directed toward phosphorus as it seems to be the limiting resource. I have not been able to calculate a mass balance on the lake since I have no area/volume/depth data. It would also be useful to do an estimate of phosphorus loading to the lake but I have not taken the time to do this.

The phytoplankton data are interesting in that the dominant taxa appear to be primarily diatoms, greens, and groups other than cyanobacteria. There was an increase in *Anacystis* and *Anabaena* in the summer but this group does not dominate the community over the months for which there are data. The data from 1982 appear to be similar. The *Anabaena* was very noticeable in late July (according to your earlier memo) when it was concentrated on the shore and certainly would be a concern from aesthetics or even health concerns. But it is interesting that most of the samples are not dominated by cyanobacteria and the numbers of cells are not as high as might be expected in a eutrophic lake. The zooplankton numbers are very high and dominated by *Daphnia* which is an ideal organism as far as an efficient grazer. I would be interested in knowing what the status of the fish population in the lake is since *Daphnia* do not do well if zooplanktivorous are present. There are some comments below in the discussion on lake management and biomanipulation.

One of your concerns is to what can be done as far as maintaining or improving the lake water quality. One of the overall problems is the size of the lake (318 ha). It is obviously much easier to manipulate a small lake but there are still things can be done with a lake the size of Tyhee. As mentioned above it would appear that the oxygen depletion problem is exacerbated by the partial mixing at turnover in spring or fall. If this were to be dealt with it might be done in one of two ways. As discussed in the 1985 objectives report, a hypolimnetic aerator would add additional dissolved oxygen to the hypolimnion while maintaining the stratification. Hypolimnetic aeration is very expensive and far more difficult than simple destratification and would be used only if there was some reason to maintain the temperature stratification such as a cold water fisheries. If this is not the case, then destratification is also an option. Because of the size of the lake, destratifcation is still expensive but more feasible than a hypolimnetic system. The key to this is whether the salmonid fishery needs to be protected or enhanced.

A second way of manipulating the lake would be to consider some biological possibilities. The internal loading is still the primary problem and would need to be dealt with but there is a potential to enhance the situation by managing the biological character of the lake. For instance, if a priority is to reduce the amount of algal standing crop and increase water clarity, one way would be to enhance the growth of zooplankton. As noted above, the lake has a healthy population of a desirable organism (*Daphnia*) which is a very efficient grazer. The strategy would be to enhance the growth and survival of this organism by minimizing the predation pressure on it by identifying and targeting the fish species responsible to reduce its numbers. This is predicated on a decision that body contact recreation, aesthetics and drinking water were more important than fisheries values. If this is not the case then this biomanipulation approach is not feasible.

The other possibility is to change the water exchange rate of the lake by diverting water into it. The lake has a relatively long water residence time (5 years) which contributes significantly to its poor water quality. The Bulkley River is within a reasonable distance and although this also would be expensive, it is a possibility as a source of additional flow through water. The exploration of this would be primarily an engineering exercise to estimate costs of such an undertaking. I would hypothesize that if the water exchange rate were reduced by half, there would certainly be a significant improvement and if reduced to one year would be substantial. I could do the calculations to check this assumption but don't have the time right now and I'm not sure if this option would even be considered.

I hope this is of some use. It is hard to get into all of the details of a situation like this in a limited time. If any of this needs clarification, contact me.

Rick Nordin

File 77530-20/Smithers

Memo

MINISTRY OF ENVIRONMENT
JUL 23 1992
ENVIRONMENTAL
PROTECTION BRANCH
SMITHERS, B.C.

To: P. Ross, Smithers
From: P.Warrington, Victoria.
Date: 21/7/92

Regarding 'Weed' Problems in the Smithers Lakes.

On July 15, 1992 I carried out a brief survey of 4 lakes in the Smithers area; Seymour, Kathlyn, Tyhee and Round. My observations are that there is not yet an aquatic weed problem in Seymour Lake, the beginnings of a problem with ***Elodea canadensis*** in Kathlyn Lake along the shore between the boat launch and the highway, and significant problems in Round and Tyhee Lakes. These qualitative observations of relative weed problems correlate well with the water retention time estimates of 0.92, 1.15, 3.1 and 5.0 as given in Boyd *et al* (1985).

Round Lake has extensive beds of ***Ceratophyllum demersum*** and ***Myriophyllum sibiricum*** all around the shoreline. These surfacing plants are generally covered in a mat of filamentous green algaeand the water column is quite murky. The ***Ceratophyllum*** and the green algae take all their nutrients from the water column. This indicates that there are considerable quantities of nutrients, especially phosphorus, dissolved in the water column, and likely a large reservoir in the sediments as well. There are several dairy farms around the shores of this small lake.

Tyhee Lake has ***Elodea canadensis*** mats and extensive shallow-water areas with dense beds of ***Myriophyllum sibiricum*** and ***Potamogeton*** spp. There are also considerable amounts of ***Lemna minor***, ***Lemna trisulca***, ***Spirodela polyrhiza***, ***Wollfia columbiana*** and ***Ceratophyllum demersum*** in the shallows and protected areas. Non of these latter species are rooted and thus all of their nutrient uptake must come from the water column. This indicates that there are considerable quantities of nutrients, especially phosphorus, dissolved in the water column, and likely a large reservoir in the sediments as well. This is borne out by documented phosphorus levels in these lakes in 1982 as reported in Boyd *et al* (1985) and subsequent measurements, recorded in SEAM, which show increases in these phosphorus levels.

There is little value in trying to control the weeds until the levels of phosphorus in the water columns are reduced below about 10-12 μg/L, since the weeds will simply grow back to nuisance levels very quickly. Phosphorus input needs to be curtailed first and then perhaps the phosphorus reservoir in the sediments can be addressed. There are phosphorus objectives in Boyd *et al* (1985) and meeting these would be a good start towards controlling the weed problems in these lakes. Action needs to be taken, the problems will not go away, they will in fact get worse, unless nutrient management takes place on a drainage basin basis.

Elodea canadensis is a relatively recent problem in Kathlyn and Tyhee Lakes. Prior surveys in 1977 did not find this species. However the problem is not unique to the Smithers area lakes since this species has been documented as moving into a number of new lakes throughout the Province in the last few years and becoming a nuisance in most cases. The reason for this sudden mobility of ***Elodea*** is not known but it is being followed with interest. In one lake the maximum level was followed by a population crash in the next year and then a gradual subsequent increase. The final outcome is not yet known as the population has not yet stabilized and annual observations continue to be made.

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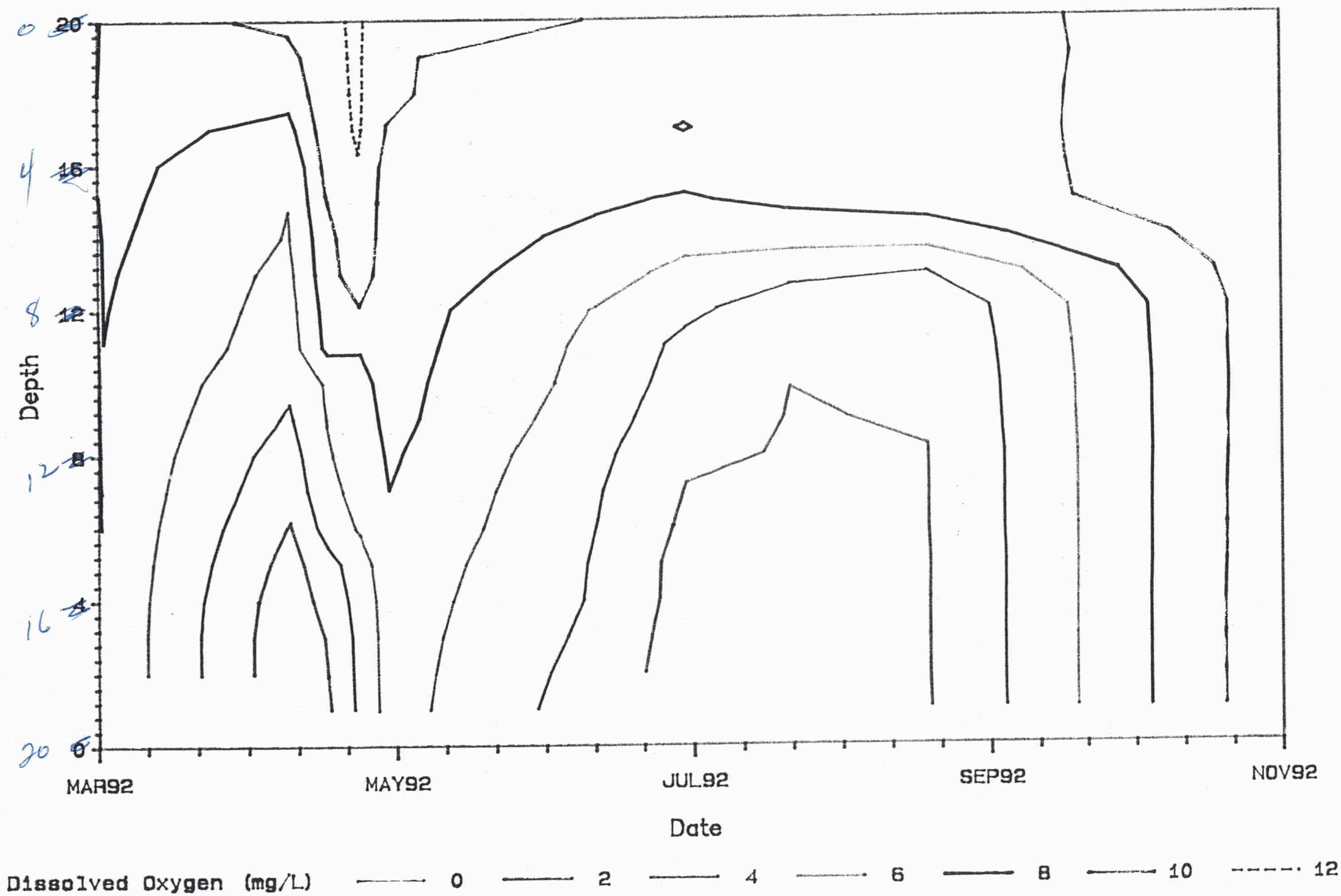
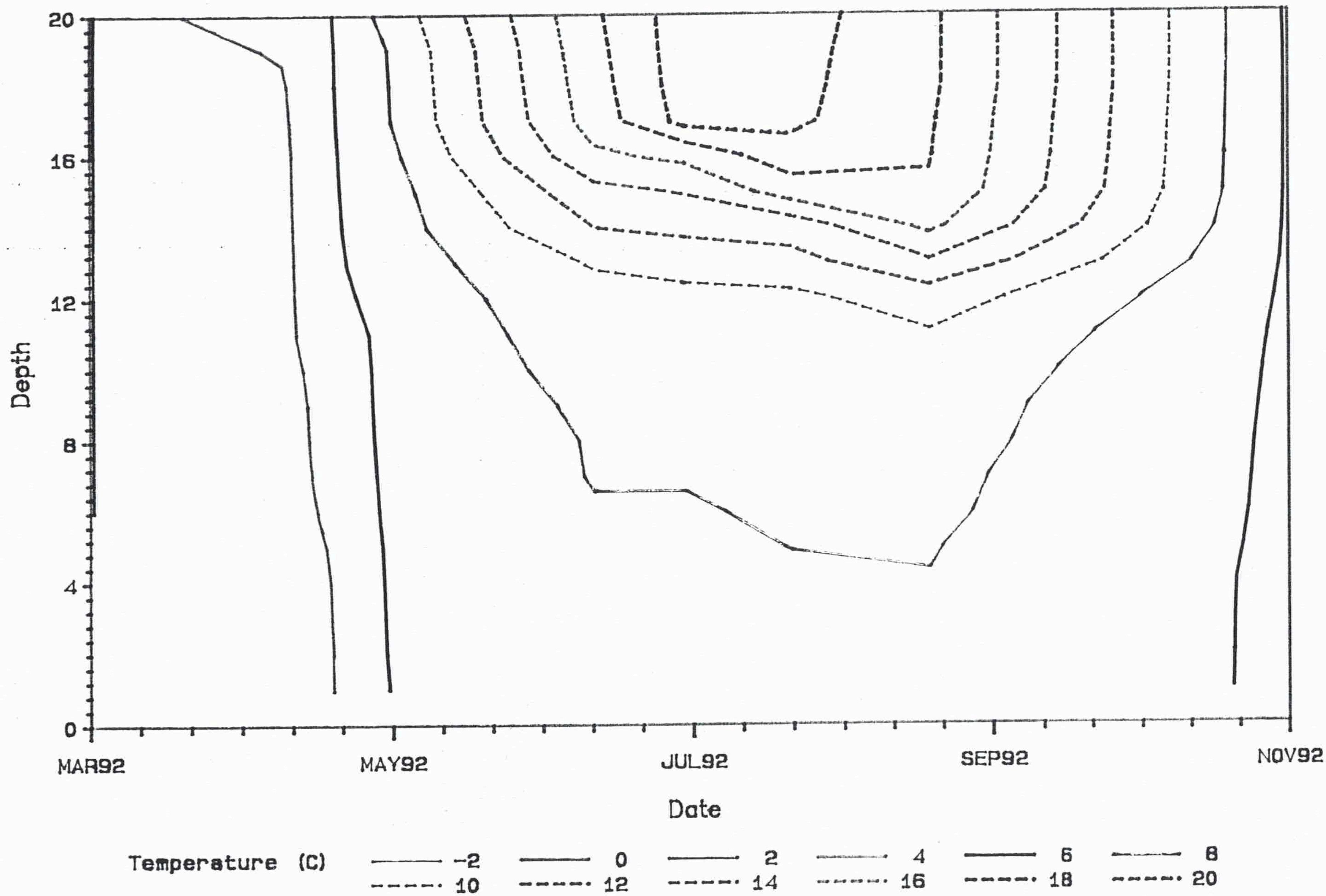
1992 Tyhee Lake Dissolved Oxygen (mg/L)



1992 Tyhee Lake Temperature



1992 Tyhee Lake Nitrogen (mg/L)