

A WATER QUALITY ASSESSMENT
OF
BLAIR LAKE, CUMBERLAND COUNTY, NOVA SCOTIA.

Prepared by

Darrell Taylor

Nova Scotia Department of Environment & Labour

February 15, 2005

TABLE OF CONTENTS

	PAGE
1. ABSTRACT.....	iii
2. ACKNOWLEDGEMENTS.....	iii
3. BACKGROUND & INTRODUCTION.....	1
4. STUDY AREA.....	1
5. METHODS.....	1
6. RESULTS & DISCUSSION.....	2
A. Lake Conditions.....	3
1. Trophic State.....	3
a) Nutrients.....	4
b) Chlorophyll.....	5
c) Transparency.....	5
2. Temperature	6
3. Dissolved Oxygen	6
4. Major Ions.....	7
5. Metals.....	11
B. Stream Conditions.....	11
7. CONCLUSIONS.....	11
8. RECOMMENDATIONS.....	12
9. REFERENCES.....	13
10. APPENDICES	

LIST OF FIGURES

Figure 1 Bathymetric Map of Blair Lake14
Figure 2 Total Phosphorus Concentrations15
Figure 3 Chlorophyll Concentrations16
Figure 4 Secchi Disk Transparency Values.....17

LIST OF TABLES

Table 1 OECD Trophic Categories for Lake..... 4
Table 2 Summary of Selected Water Quality Parameters - Lake Appendix A
Table 3 Summary of Selected Water Quality Parameters - Streams..... Appendix B

ABSTRACT

A water quality investigation was undertaken on Blair Lake and its inlet streams in order to address concerns related to recently reported impaired conditions. Lake conditions in the fall of 2003 were anecdotally reported by community members as being highly turbid, green, and having an objectionable odour. Past studies, including the 1986 study undertaken by the Cumberland County District Planning Commission, had indicated high concentrations of nutrients and chlorophyll a (an indicator of algal production) as well as low transparency, all indicating eutrophic conditions. Various options and recommendations aimed at improving Blair Lake water quality were included in the 1986 report, but no record of implementation has been found. The intent of the current investigation was to determine present day water quality in the lake and assess trends since the previous study. This in turn would serve as the basis for subsequent discussions on management options which may wish to be explored to improve water quality.

A sampling program was set up to determine chemical water quality at three lake locations, as well as three inlet streams. Sampling occurred on two occasions during the late summer/early fall period to capture the worst case scenario of water quality conditions for the year. Sampling protocols, stations, dates, and water quality parameters duplicated the 1986 study as much as possible, in order to provide consistent results for comparison purposes.

Results from the current study suggest that Blair Lake, as a whole, was very productive. Nutrient, chlorophyll a concentrations, and Secchi disk transparency indicated eutrophic conditions at levels as high or higher than those reported in 1986. Inlet streams showed indications of nutrient enrichment as well, and at levels similar to those reported in the 1986 study. No identification or assessment of nutrient sources contributing to these conditions was undertaken, since this was initiated in the CCDPC report and is beyond the scope of the current investigation and available resources.

ACKNOWLEDGEMENTS

The water quality sampling program was jointly undertaken by Central and Regional Office staff from the Nova Scotia Department of Environment & Labour (NSEL) and Town of Amherst Engineering Department staff.

Assistance was also provided to this initiative by the Amherst Fire Department who provided boat, motor and associated equipment to transport those collecting samples to various stations on the lake.

Data entry and management was provided by Natalie LeBlanc, Town of Amherst Engineering Department, who created an electronic database of historic and present day information. Alan Tattrie and Carmella Robertson (NSEL) also contributed significantly to data processing and analysis.

Special thanks to staff of the Town of Amherst for both their field efforts (Ron Patterson and Andrew Fisher) and clerical efforts (Natalie Le Blanc), without who's help this study would not have been possible.

Appreciation is extended to all who were involved and in any way contributed to this endeavour.

BACKGROUND & INTRODUCTION

During the period of August to September of 2004 a water quality monitoring program was undertaken on Blair Lake and its associated inlet streams. This program was initiated in response to recent concerns brought forward by local residents relating to perceived impaired water quality. Background information leading to this initiative is outlined in the following text.

In the early 1980's the Cumberland County District Planning Commission (CCDPC) undertook a study to determine baseline water quality in several lakes near Amherst which were seen as valuable water resources for either commercial or recreational use. This was done in conjunction with the development of a comprehensive Municipal Planning Strategy and associated Land Use By-laws to protect these valuable water resources. A report was subsequently produced in 1986 which determined baseline conditions in Blair Lake, and indicated high nutrient concentrations and eutrophic conditions which were deemed an impairment to desired water uses. This report included recommendations for actions which would improve water quality in Blair Lake. Subsequently the Cumberland County District Planning Commission was disbanded and Planning Strategies adopted by the Municipality. To the author's knowledge, recommendations outlined in the 1986 report were not adopted or implemented.

Within this context, the purpose of the current study was to determine the status of present-day water quality, particularly in terms of nutrient concentrations and trophic status, and to assess trends relative to baseline water quality previously established during the 1986 study.

This study is not intended to be a comprehensive water quality assessment, but rather to provide a scientifically defensible indication whether water quality has improved, remained the same, or deteriorated since the previous study undertaken in the early 1980s. This information in turn can serve as the basis for subsequent discussions about possible management options (including those recommended in the CCDPC report) which may wish to be explored to improve water quality.

STUDY AREA

Blair Lake and the surrounding area are amply described in the 1986 CCDPC report which should be referenced for particulars in this regard.

METHODS

During August-September of 2004, a sampling program was undertaken in Blair Lake whereby physical and chemical characteristics of water quality were investigated, primarily to determine nutrient levels and associated trophic state¹. Water temperature and dissolved oxygen profiles were determined in the field using a model 57 YSI meter while transparency or clarity was determined using a standard 20 cm Secchi disk. Water samples were collected at the lake surface (i.e. 0.5 meter depth) using a 2 litre Van Dorn type water sampler and placed in new clean 500 ml polyethylene

¹Trophic state refers to the level of biological productivity in a waterbody.

bottles and further rinsed with lake water. This procedure was repeated at three stations on the lake, including a near- bottom location at the deepest station (i.e. station #3 -see Figure 1).

Nutrient and chlorophyll a concentrations were determined in samples taken at a depth of 0.5 m below the surface (hereafter referred to as surface samples) at all lake stations. In addition, a sample was collected at 1 m above the bottom (hereafter referred to as bottom samples) to assess any water quality differences over depth. Secchi disk transparency was also determined at each of the three lake stations. Metal and major ion concentrations were determined from all samples taken in the lake.

Inlet streams were sampled for water quality as well, with temperature and relative flow recorded.

If in-lake nutrient concentrations were found to be high, relative proportions of nutrient contributions from each sub-watershed could be determined from the stream data. This would enable a prioritized approach to be taken with respect to remedial action should major sources of nutrients be identified from the watershed. Although this was beyond the scope of this study, subsequent investigators should find this information useful.

All samples were kept cool and in the dark prior to lab analysis. Subsequently, samples were shipped to the lab such that analysis was performed within 24 hours of collection, as per APHA standard protocols.

Laboratory analysis was performed at the Environmental Chemistry Lab of the Queen Elizabeth II Health Science Center (QE II) where analytical procedures were undertaken in accordance with established protocols outlined in "Standard Methods for the Examination of Water and Waste Water" (APHA 1991).

RESULTS AND DISCUSSION

The chemical water quality characteristics or parameters which were measured during this study can be divided into three broad categories. These include parameters necessary to determine trophic state (i.e. nutrients, chlorophyll, transparency), major ions and metals. The first category was given primary consideration due to the nature of the expressed concerns as well as potential impacts from local land uses. The latter two categories were included in order to ensure quality assurance of the data set and for further assessment if required.

As outlined in the previous section, physical characteristics were investigated in terms of water temperature and dissolved oxygen profiles for all lake stations as well as temperature and relative flows at stream locations. Both chemical and physical data are presented in Tables 2 and 3 in Appendix A and B.

Results from each of the above areas of investigation are presented in applicable tables, as indicated, and are discussed below.

LAKE CONDITIONS

Trophic State

Trophic state refers to the level of biological productivity within a lake gauged over a range of very unproductive (oligotrophic) conditions to very productive (eutrophic) conditions. Conditions midway between these two extremes are termed mesotrophic. A progression from very unproductive to very productive conditions typifies the natural lake aging process and is termed eutrophication. This process, which involves the lake basin gradually infilling with silt and organic matter, takes thousands of years to complete and eventually causes the lake to evolve back to dry land. Manmade influences that contribute additional nutrients, organic matter and sediment to a lake can greatly accelerate this process and cause the lake to infill at a much faster rate. This accelerated process is termed cultural eutrophication.

Three key indicators of trophic state have been established. They are generally recognized as being chlorophyll a, total nutrient concentrations (either phosphorus or nitrogen), and transparency as determined by a Secchi disk.

Chlorophyll a concentration has been shown to correlate well with levels of algal biomass (Nicholls and Dillon 1978). Additionally, strong correlations between chlorophyll a, total nutrient concentration and transparency have been shown, based on mean annual or mean ice-free season concentrations. (Dillon and Rigler 1974, Vollenweider and Kerekes 1980, Clark and Hutchison 1992).

Total nutrient concentrations represent the chemical response of a lake to eutrophication while chlorophyll a concentrations represent the biological response, and transparency represents the physical response. Together these water quality parameters provide an excellent indication of trophic state when monitored over a full growing season and taken in the context of the lake as a whole.

However, due to both time and resource constraints mean annual or ice-free season concentrations were not determined. As a surrogate, nutrient, chlorophyll, and transparency values were determined during the end of summer period with associated peak water temperatures for the year. This period was chosen to represent the “worst case scenario” situation, where algal production and chlorophyll concentrations should be at peak values for the year.

These water quality parameters are addressed in the following text and existing and historic water quality is compared to established values for trophic state categories (OECD 1982) as presented in Table 2.

Table 1

**PROPOSED BOUNDARY VALUES FOR TROPHIC CATEGORIES (OECD 1982)
(fixed boundary system)**

Trophic Category	(P)	(chl)	(max chl)	(Sec)	(min sec)
	mg/m ³			Meters	
Ultra-oligotrophic	< 4.0	<1.0	<2.5	>12.0	>6.0
Oligotrophic	<10.0	<2.5	<8.0	>6.0	>3.0
Mesotrophic	10 - 35	2.5 - 8	8 - 25	6 - 3	3 - 1.5
Eutrophic	35 -100	8 - 25	25 - 75	3 - 1.5	1.5 - 0.7
Hypertrophic	>100	>25	>75	<1.5	<0.7

- (P) annual mean in-lake total phosphorus concentration
(chl) annual mean chlorophyll a concentration
(max chl) annual maximum chlorophyll a
(sec) annual mean Secchi disk transparency
(min sec) annual minimum Secchi disk transparency

Nutrients

Nutrients investigated in this study include two species of phosphorus - ortho phosphorus and total phosphorus (Total P), and three species of nitrogen - nitrate + nitrite, ammonia, and total nitrogen (Total N). Results for these parameters are found in Tables 2 and 3, Appendix A and B.

Total nutrient concentrations (i.e. both organic and inorganic species, as in Total P and Total N) are considered to be the best chemical indicators of trophic state (OECD 1982, Clark & Hutchison 1992) and therefore, are of primary interest to this investigation. Ratios of Total N to Total P concentrations can be used to determine which nutrient is in shortest supply and therefore is the limiting nutrient for plant growth in any given lake. It has been shown that if the Total N/Total P ratio is greater than 17:1 phosphorus is limiting; less than 17:1 nitrogen is limiting (OECD 1982). In Blair Lake, as in most lakes, P was shown to be limiting as indicated from the calculated ratios provided in the 1986 CCDPC report.

Total P concentrations during the 2004 sampling period ranged from a minimum of 47 ug/l at station #1 on July 29th to a maximum of 98 ug/l at station #8 on September 16th.

Total P concentrations from samples taken at station #3 (mid-lake) during the summer of 2004 are compared to those taken in the 1986 study as well as established trophic categories, and are presented in Figure 2.

The Total P values shown in Figure 2 indicate that Blair Lake nutrient values have varied significantly over time, but are currently roughly comparable to historic levels. These values also indicate eutrophic or highly nutrient rich conditions.

Chlorophyll

Primary productivity can be defined for the purpose of this study as being the extent of microscopic plant life or algal production in the water column as a result of available nutrients. The most commonly accepted indicator to quantify this primary productivity or algal biomass is obtained by measuring the chlorophyll a concentration in representative water samples. Chlorophyll a concentrations have been shown to correlate extremely well with algal biomass (Nicholls and Dillon 1978). Therefore, an increase in Chlorophyll a concentrations indicate an associated and proportional increase in algal biomass or density.

As in the case of nutrients, algal population growth can vary significantly, over time and space. Therefore, the sampling protocol was established to address this variability as outlined in the previous section.

Chlorophyll concentrations ranged from a minimum of 25.8 mg/m³ at station #1 on July 29th to a maximum of 155 mg/m³ at station #8 on the same date. Results indicate that chlorophyll concentrations progressively increased from station #1 at the north end of the lake to station #8 at the southern end of the lake.

Chlorophyll concentrations recorded at the mid-lake station (station #3) are most representative of the lake as a whole and are presented as a time series from 1882 to 2004 in the following graph (Figure 3). Chlorophyll values for the July 29th and September 16th sampling dates in 2004 were 92.3 and 134 mg/ cm³ respectively.

The seasonal peak chlorophyll data indicate that 2004 values are significantly higher than values from the 1980s. When compared with the OECD eutrophication tables (Table 2), current chlorophyll values indicates that Blair Lake falls into the hyper-eutrophic category and is very productive.

Transparency

Transparency, as determined by a Secchi disk depth, is considered a good indicator of productivity and trophic state when suspended sediment and highly coloured waters are not present to bias results (OECD 1982). During this study, samples exhibited a mean colour value of 40.2 True Colour Units (TCU). Secchi measurements were not taken during or immediately following any major rain event. At least 24 hours following any significant rain event was used as a requirement of any given sampling date. Given these conditions, Secchi depth transparency is considered to be an appropriate indicator of algal production and therefore trophic state.

Secchi depths ranged from a minimum of 0.37 meters at station # 3 on September 16th to a maximum of 0.88 meters at station # 1 on July 29th. The Secchi disk values reported appear to be directly related to chlorophyll concentrations at the respective sampling locations. Transparency values were only consistently recorded at one station (station # 1) during past and present studies. Transparency values recorded at station # 1 are presented as a time series from 1982 to 2004 in the following graph (Figure 4).

The seasonal low transparency data indicate that 2004 values are roughly the same or slightly lower than values from the 1980s. When compared with the OECD eutrophication tables (Table 2), current transparency values indicate that Blair Lake falls into the eutrophic or hyper-eutrophic category and is very productive.

In summary, the primary indicators of trophic state, chlorophyll *a*, total phosphorus, and transparency suggest that eutrophic conditions existed in Blair Lake during this study. The lake as a whole was nutrient rich, and biologically very productive with respect to algal growth, with associated low transparency due to the significant algal populations present.

Temperature:

Temperature profiles were recorded for the entire water column at each lake station. From this data it was determined whether thermal stratification existed at that time. This information, in association with dissolved oxygen concentrations, was primarily used to interpret analytical results.

The lake was not observed to thermally stratify significantly during the summer period.

Dissolved Oxygen:

Dissolved oxygen profiles were recorded concurrently with water temperature at all lake stations. As indicated above, dissolved oxygen concentrations were primarily used in interpreting analytical results but were additionally used to determine probability of nutrient reintroduction from bottom sediments.

The minimum concentration of dissolved oxygen recorded was approximately 4 mg/l at the bottom of station #13 on September 16th.

In summary, temperature and dissolved oxygen profiles did not indicate significant thermal stratification in the lake during the summer of the study period. Dissolved oxygen concentrations remained relatively high. Therefore, the reintroduction of nutrients from the bottom sediments as a result of hypolimnetic oxygen depletions may not be considered to be extensive.

Major Ions

Ions are both negatively and positively charged particles which are found dissolved in water. These include substances which may be considered to be nutrients and metals, but for the purpose of this study refer to all other common substances found in solution.

A list of these water quality parameters and associated results are found in Table 2 (Appendix A). Concentrations of these parameters are presented over time between 1982 to 2004, with summary statistics calculated (i.e. minimum, maximum, and mean values). No further analysis or interpretation of these parameters are provided at this time.

However, a brief explanation follows of each parameter, its environmental significance, and typical values expected in natural surface waters in Nova Scotia.

pH:

The pH of a solution refers to the hydrogen ion concentration or the relative acidic/basic nature of the solution expressed on a scale of 0 to 14, with a neutral pH at 7.

In natural aquatic systems, the pH usually results from the geology and geochemistry of the rocks and soils of the watershed or drainage basin. For surface waters, the pH range of interest is typically 4 to 11 (CCME 1987).

Alkalinity:

Alkalinity refers to the capacity of a solution to neutralize acid and in natural waters is primarily the result of carbonate and bicarbonate ions. Because of the predominant effect of carbonate, alkalinity is expressed in equivalent amounts of calcium carbonate (CaCO_3). Concentrations of carbonate and bicarbonate in surface waters result in large part from the natural weathering of rock in the watershed. Greater concentrations are found, and therefore, higher alkalinity exists where sedimentary or metamorphic bedrock is present. Such is the case with Blair Lake where sedimentary bedrock predominates in the watershed.

In natural surface waters alkalinity varies greatly. In Nova Scotia concentrations are generally less than 50 mg/l unless limestone deposits are in close proximity. In such cases concentrations can more than double. Conversely, in areas of non-carbonate bedrock, alkalinities below detectable limits are common.

Conductivity:

Conductivity refers to the ability of a substance to conduct an electric current. In an aqueous solution this measurement is dependent upon the total concentration of dissolved substances and the solution's temperature.

The conductivity of natural fresh waters varies greatly and may range from less than 20 umhos/cm in dilute waters to over several hundred or more in waters influenced by limestone or salt deposits.

Colour:

The true colour of water refers to the colour resulting from substances which are totally dissolved in the solution. It is not to be mistaken for apparent colour resulting from suspended or colloidal matter. The colour in natural waters are primarily due to coloured organic substances, known as humic substances, resulting from the decay or aqueous extraction of vegetation. The presence of metals such as iron, manganese, and copper which are weathered from rock can also contribute to colour, but this situation predominates in groundwater.

Natural surface waters in Nova Scotia may range in colour from less than detectable limits, in many cases, to over 100 True Colour Units (TCU), in a very limited number of cases where bog lakes are encountered. Average colour values are usually less than 45 TCU.

Turbidity:

Turbidity measurements provide an approximation for concentrations of suspended material such as clay, sand, silt, finely divided organic and inorganic matter, plankton and other microorganisms in water.

Total Organic Carbon:

Total organic carbon (TOC) refers to the total of suspended and dissolved organic constituents of water. Elevated levels of TOC are primarily indicative of naturally occurring organic matter such as humic substances but also can reflect high algal concentrations. Levels of organic carbon in surface waters vary widely, ranging from non-detectable in newly risen rivers supplied by limestone springs to greater than 100 mg/l in peaty swamp waters (Croll 1972).

Hardness:

Hardness is a traditional measure of the capacity of water to react with soap and is expressed in terms of mg/l of CaCO₃.

In fresh water the principal hardness-causing ions are calcium and magnesium which naturally leach from rock and soils. Soft water is considered to have a value of 0 to 60 mg/l, medium hard 60 to 120 mg/l, hard 120 to 180 mg/l, and very hard 180 mg/l and above (Health and Welfare Canada 1980).

Natural fresh waters in Nova Scotia are almost invariably soft, if not in close proximity to limestone or salt deposits.

Sodium:

Sodium is a non-toxic metal which is abundant, widely distributed in nature, and present to some extent in all natural waters. The principal sources of sodium are from the weathering of igneous rock and salt deposits, as well as the leaching of soils. Deicing salt used on highways can also significantly contribute to overall sodium levels in nearby watercourses. Concentrations in pristine surface waters vary greatly, ranging from less than 1 mg/l to over 300 mg/l, depending upon amount of rainfall and evaporation, and geologic formations present. Typical undisturbed lakes in Nova Scotia however would have sodium concentrations generally less than 50 mg/l.

Potassium:

Potassium is a widely distributed non-toxic element which is essential to plant and animal nutrition. The primary natural source is from the weathering of rock. Although potassium may be found in many rocks, those with significant amounts (e.g. granite) are resistant to weathering. Commercial chemical fertilizers contain substantial concentrations of this element and may be a significant cultural source from the watershed.

Concentrations of potassium in natural surface waters seldom reach 20 mg/l and are generally less than 10 mg/l (CCME 1987).

Calcium:

Calcium is one of the most abundant cations (positively charged ions) found in surface or groundwaters. It is readily soluble in water and enters the aquatic environment through the weathering of rocks, especially limestone, and from the soil, through seepage and run-off. Calcium

salts, along with those of magnesium, are primarily responsible for the hardness of water. This element is considered to be essential for nearly all living organisms.

The concentrations of calcium in natural fresh waters vary according to the proximity of calcium-rich geological formations. Typical concentrations are less than 15 mg/l, whereas waters close to carbonate rocks may have concentrations in the range of 30-100 mg/l. (CCME 1987)

Magnesium:

Magnesium is the eighth most abundant natural element in the earth's crust and is a common constituent of natural water (CCME 1987). The principal sources of magnesium are ferromagnesium minerals in igneous rocks and magnesium carbonates in sedimentary rocks. Along with calcium, it is one of the main contributors to water hardness, and is also considered to be an essential element for all living organisms.

Water in watersheds with magnesium-containing rock may have magnesium in the concentration range of 1 to 100 mg/l.

Sulphate:

Sulphate is widely distributed and is an ionic component of all natural waters. It may be leached from most sedimentary rocks, including shales, with the most appreciable contributions from such sulphate deposits as gypsum and anhydrite. Acid rain can also contribute to sulphate concentrations in surface waters.

Concentrations normally vary from 10 to 80 mg/l in naturally occurring surface waters (CCME 1987).

Chloride:

Chloride is widely distributed in the environment, generally as sodium chloride, potassium chloride, and calcium chloride (CCME 1987). The weathering and leaching of sedimentary rocks and soils and the dissolution of salt deposits release chlorides to water (Mc Neely et al. 1979). In natural waters, chlorides are present in low concentrations, commonly less than 50 mg/l. Deicing salts applied to highways can contribute significantly to chloride concentrations where extensive urbanization has occurred.

Silica:

Silicon is a stable, relatively light chemical element that does not occur free in nature, but combines with oxygen and other elements to form oxides of silicates (CCME 1987). The term "silica" refers to silicon in natural waters, and is usually represented by the hydrated form of the oxide. Silica is present in most rocks, but many are resistant to chemical weathering. Although relatively unreactive chemically, silicon is considered an essential micronutrient to some algal species, most notably the diatoms. Therefore, silicon concentrations in freshwaters are significantly influenced by diatom cycling.

Most natural waters contain less than 5 mg/l of silica, although a range of 1 to 30 mg/l is not uncommon. Typical surface waters have a silica concentration of 3 to 4 mg/l (McNeely et al. 1979).

Metals

Dissolved metals which were investigated during this study are listed, along with results, in Table 2. (Appendix A). As with major ions, concentrations of specific metals are presented over time from 1982 to 2004, with summary statistics calculated (i.e. minimum, maximum, and mean values). No further analysis or interpretation of these parameters is provided at this time.

STREAM CONDITIONS

Stream water quality for selected parameters is presented in Table 3 (Appendix B). Concentrations of selected parameters are presented over time from 1982 to 2004, with summary statistics calculated (i.e. minimum, maximum, and mean values). No further analysis or interpretation of these parameters is provided at this time.

CONCLUSIONS

Based on the results of this study, it can be concluded that Blair Lake, as a whole, is very productive with respect to algal growth and can be classified as eutrophic. Relatively rough comparisons of nutrient related water quality parameters between 1982 and 2004 indicate either unchanged or somewhat deteriorating conditions. Tributary streams to Blair Lake appear to have relatively high nutrient concentrations, which have remained so since the 1980s. Reintroduction of nutrients from bottom sediments to the water column as a result of hypolimnetic oxygen depletions may not be considered to be extensive due to the weak thermal stratification observed.

RECOMMENDATIONS

Blair Lake appears to be sensitive to nutrient inputs as shown by significant recurring algal blooms. Although the natural geological setting of the area tends to contribute more nutrients than other areas of the province, human related nutrient sources identified in the CCDPC report may still be impacting the lake and should be addressed.

In order to improve water quality in Blair Lake and to ensure that desired water uses are not compromised, it would be advisable to reconsider the recommendations made in the CCDPC report.

Watershed management practices should be implemented in order to minimize the export of phosphorus from the watershed thereby assuring low nutrient and high transparency in-lake conditions to the greatest degree possible. Development in the watershed (e.g. forestry, farming, residential, etc.) can be accommodated without negative impacts to water quality as long as it is undertaken in an environmentally acceptable manner. Buffer strips, erosion control measures, good livestock manure management, suitable sewage disposal systems, are examples of appropriate practices which must be implemented if the water resource is to continue to provide the expected uses to area residents.

References

1. American Public Health Association (APHA) 1992. Standard Methods for the Examination of Water and Wastewater.
2. Clark, B. and N.J. Hutchison.1992. Measuring the trophic status of lakes - Sampling Protocols. Ont. Ministry of Environment, 36p
3. Croll, B.J., Organic Pollutants in Water, Water Treatment Exam. 21, 213.
4. Cumberland County District Planning Commission. 1986. Blair Lake Water Quality Monitoring Program Report. 43 p + Appendices.
5. Dillon, P.J. and F.H. Rigler 1974. The phosphorus chlorophyll relationship in lakes. *Limnol. Oceanogr.* 19: 767-773
6. Marshall, C.T., A. Morin and R.H. Peters 1988. Estimate of mean chlorophyll a concentrations: Precision, accuracy, and sampling design. *Wat. Res. Bull.* 24: 1027-1034.
7. Marshall, C.T. and R.H. Peters 1989. General patterns in the seasonal development of chlorophyll a for temperate lakes. *Limnol Oceanogr.* 34: 856-867.
8. McNeely, R.N., V.P. Neimanis and L. Dwyer, 1979.
In: Water Quality Source book. A Guide to Water Quality Parameters. Water Quality Branch, Inland Waters Directorate, Environment Canada, Ottawa.
9. Nicholls, K.H. and P.J. Dillon 1978. An evaluation of phosphorus-chlorophyll-phytoplankton relationships for lakes. *Int. Revue Gesamten Hydrobiol.* 63: 141-154.
10. Organization for Economic and Cooperative Development (OECD) 1982. Eutrophication of waters - monitoring, assessment and control. 154 pp.
11. Vollenweider, R.A. and J. Kerekes. 1980. Synthesis report. Cooperative Programme on Monitoring of Inland Waters (Eutrophication Control), Rep. Technical Bureau, Water Management Sector Group, Organization for Economic Cooperation and Development (OECD), Paris. 290 pp.
12. Welch, P.S. 1963. *Limnological Methods.*
13. Wetzel, R.G. 1975. *Limnology.* W.B. Saunders Co., Philadelphia, Pennsylvania. 743 pp.

Figure 1

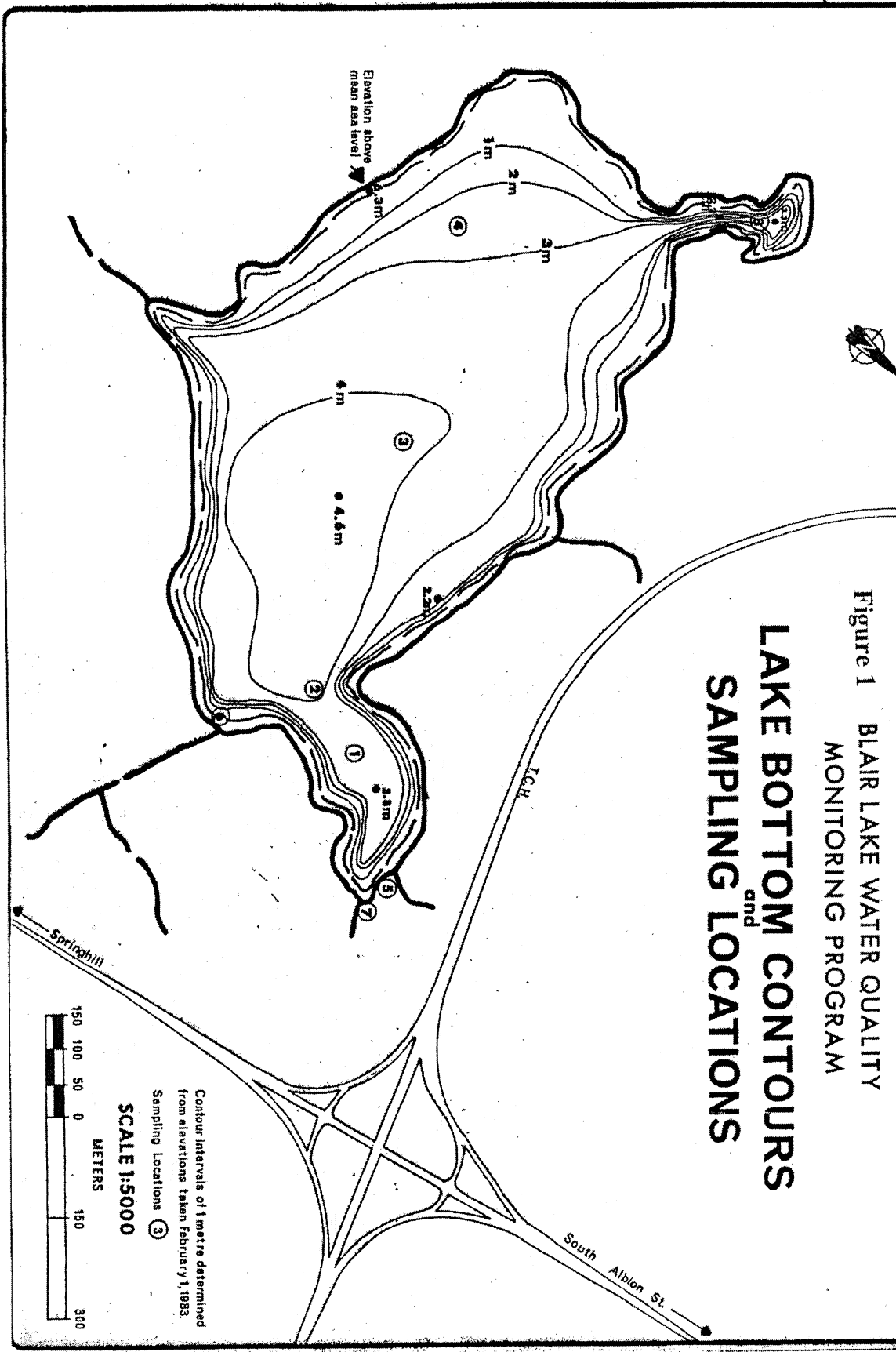


Figure 2

Total Phosphorous - Blair Lake DS3 1982 to 2004

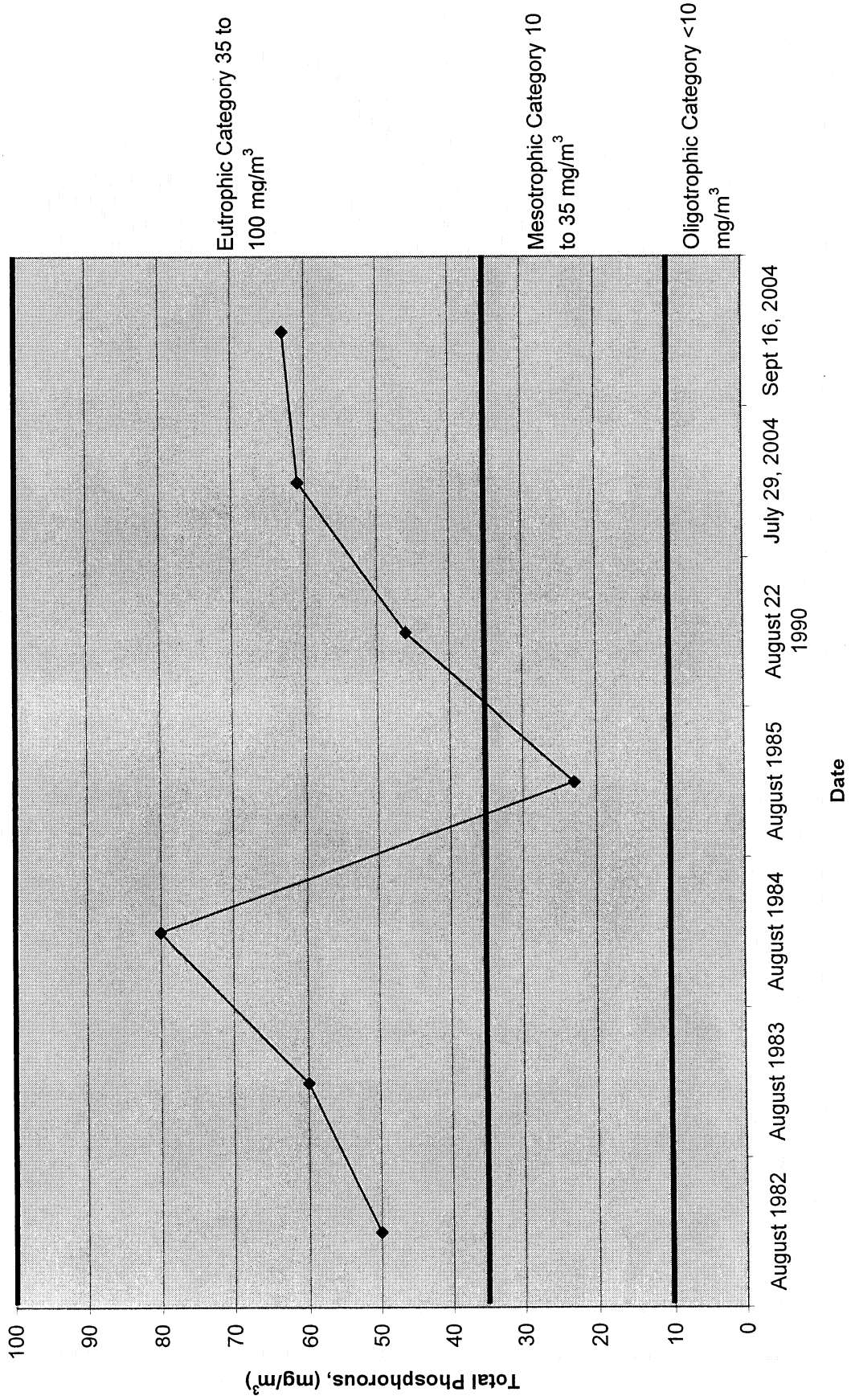


Figure 3

Chlorophyll *a* - Blair Lake DS3 1982-2004

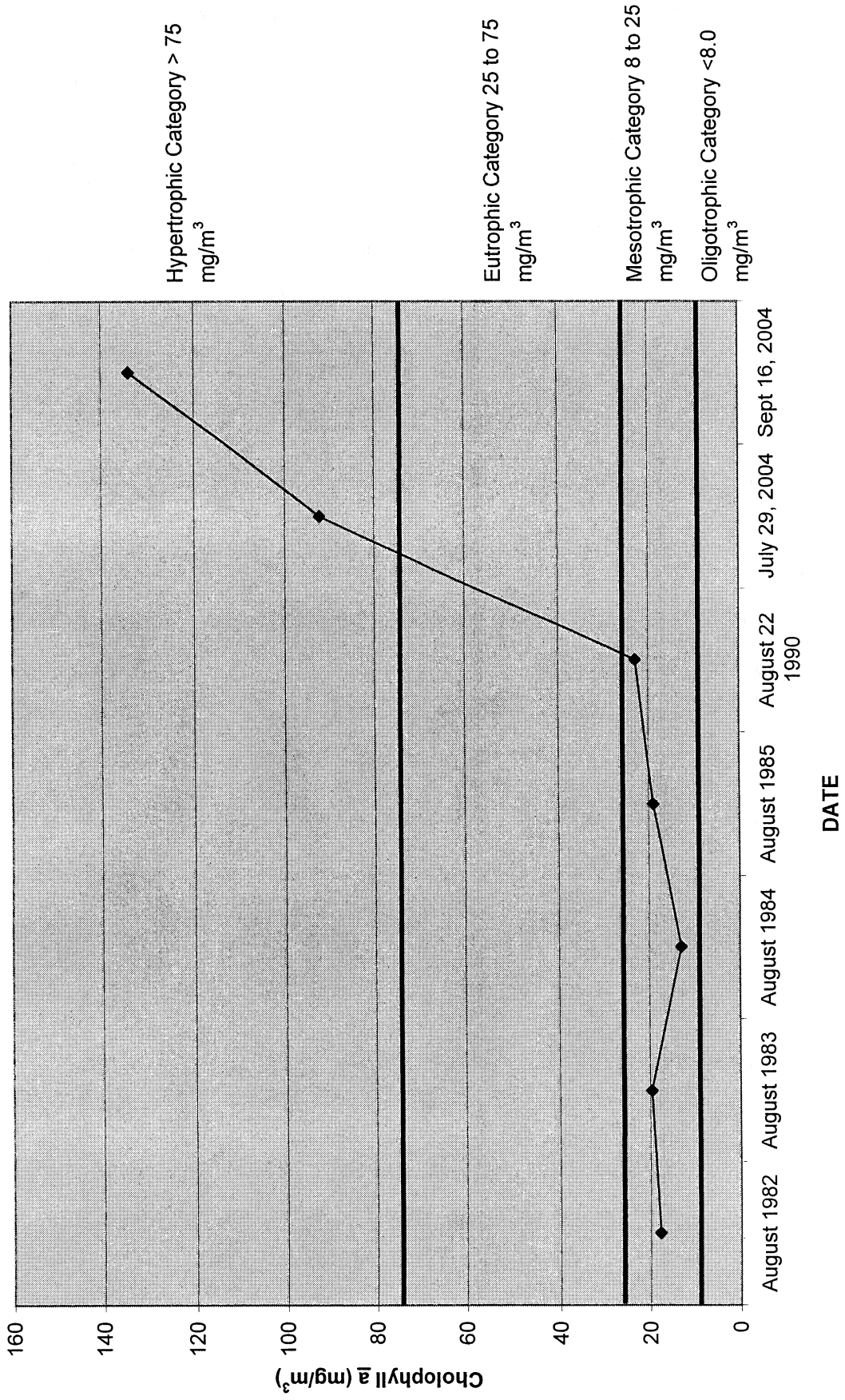
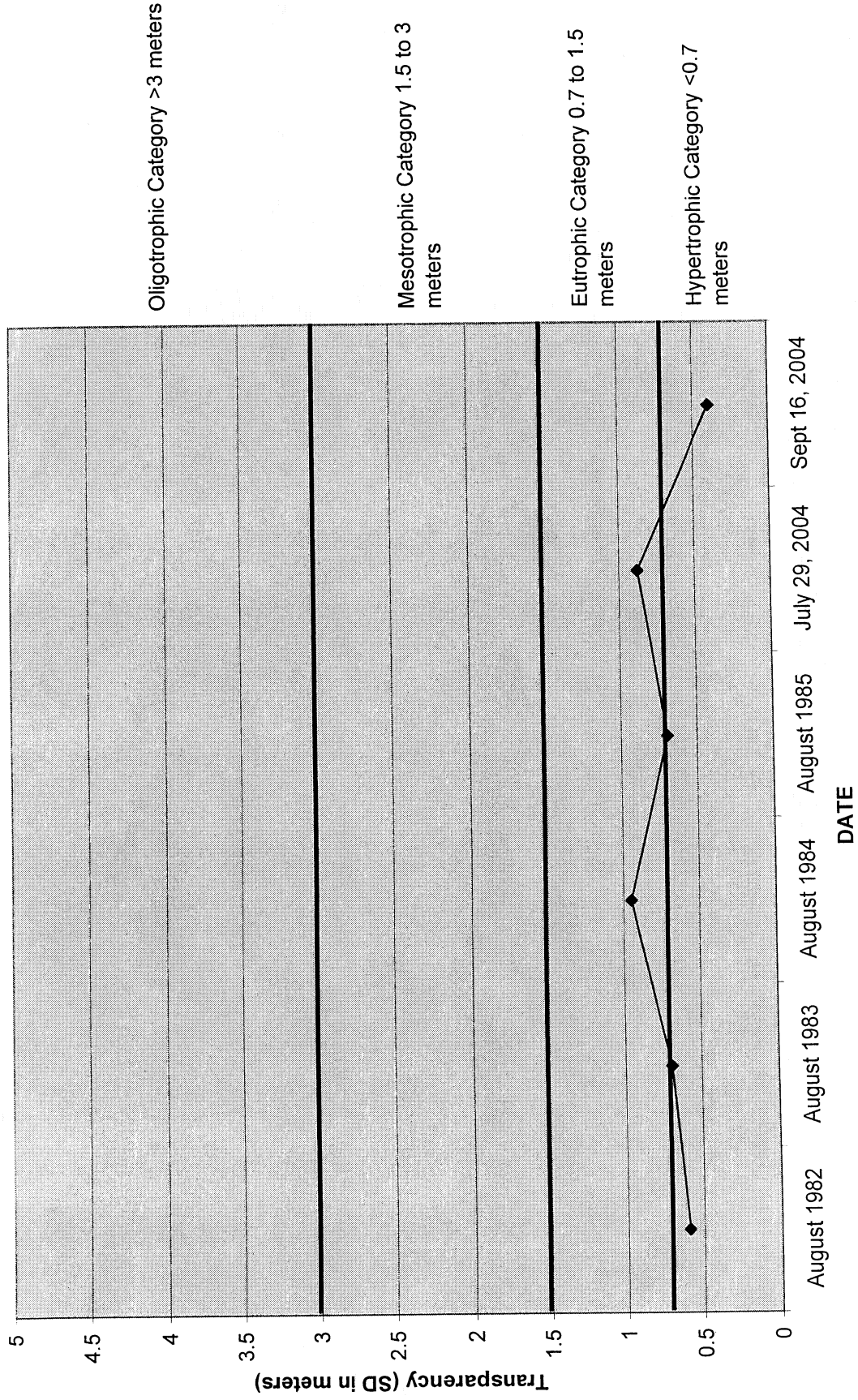


Figure 4

Transparency - Blair Lake DS1 1982 To 2004



APPENDIX A STATION 1

BLAIR LAKE WATER QUALITY MONITORING PROGRAM - SAMPLING RESULTS - STATION 1										
PARAMETERS	August 1982	August 1983	August 1984	August 1985	August 22 1990	July 29, 2004	Sept 16, 2004	MIN	MAX	MEAN
Total Phosphorous	0.08	0.07	0.106	0.04	0.042	0.047	0.063	0.04	0.106	0.064
Chlorophyll a mg/cubic m	6.1	15.3	16.3	18	22.3	25.8	108	6.1	108	30.3
Transparency (SD in meters)	0.6	0.7	0.95	0.7		0.88	0.4	0.4	0.95	0.705
Sodium mg/l	33	25	25	25		65.7	73.6	25	73.6	44.5
Alkalinity mg/l	39	39	36	39		56	52	36	56	44.4
Chloride mg/l	46	37	39			104	108	37	108	66.8
Ortho-Phosphorous (as P) mg/L	0.07	0.03	0.05	<0.02		0.003	0.005	0.003	0.07	0.028
Suspended Solids mg/l	22	17.3	19.8		17			17	22	19.0
Colour T.C.U.	100	55	62.5			18	59	18	100	58.9
Turbidity J.T.U	24	3.3	16			2.8	6.38	2.8	24	10.5
Conductivity (umho/cm)	250	240	230			499	486	230	499	341.0
pH	9.4	8.8	9.5			7.4	7.6	7.4	9.5	8.5
Total Organic Carbon mg/l	7.1	7.8	9.4			7	9.7	7	9.7	8.2
Total Nitrogen mg/l	1.7	1.3	1.6	1.25		0.65	1.7	0.65	1.7	1.4
Nitrate & Nitrite mg/l	<0.05	<0.05		0.05		0.01	<0.01	0.01	0.05	0.023
Potassium mg/l	1.8	2				2.5	2.9	1.8	2.9	2.3
Calcium mg/l	18	16				24.2	23.4	16	24.2	20.4
Magnesium mg/l	2.7	2.6				3.1	3.4	2.6	3.4	3.0
Hardness mg/l	56	50.7				73.1	72.4	50.7	73.1	63.1
Sulfate mg/l	20	14				12	17	12	20	15.8
Fluoride mg/l	0.2	0.1						0.1	0.2	0.2
Silica, reactive mg/l	3.3	3.7				2.9	7.8	2.9	7.8	4.4
Ammonia (as N) mg/l	<0.05	<0.05				0.23	0.28	0.23	0.28	0.140
Total Dissolved Solids mg/l	165	134						134	165	149.5
Mercury ug/l		<1.0								
Aluminum mg/l	0.08	0.09				0.009	0.031	0.009	0.09	0.1
Arsenic mg/l	<0.005									
Iron mg/l	0.12					0.084	0.123	0.084	0.123	0.1
Manganese mg/l	0.12					0.157	0.097	0.097	0.157	0.1
Lead mg/l	<0.002									
Copper mg/l	<0.01					<0.002	<0.002	<0.002	<0.002	
Zinc mg/l	0.02					<0.002	0.012	0.012	0.02	0.0

BLAIR LAKE WATER QUALITY MONITORING PROGRAM - SAMPLING RESULTS - STATION 3

- 1M Depth

APPENDIX A STATION 3

PARAMETERS	August 1982	August 1983	August 1984	August 1985	August 22 1990	July 29, 2004	Sept 16, 2004	MIN	MAX	MEAN
Total Phosphorous mg/m ³	17.8	50	60	80	23	46	61	23000	80000	54714.2857
Chlorophyll a mg/cubic m			19.6	12.9	19	22.9	134	12.9	134	45.5
Transparency (SD in meters)							0.37			0.585
Sodium mg/l	28		24	25			71	24	71	42.6
Alkalinity mg/l	38		38	44			50	38	56	45.2
Chloride mg/l	44		36	39			108	36	108	66.0
Ortho-Phosphorous (as P) mg	0.06		<.02	0.02	0.02		0.005	0.003	0.06	0.020
Suspended Solids mg/l	14.4		13.1	9.8		19		9.8	19	14.1
Colour T.C.U.	45		50	20			57	20	57	39.8
Turbidity J.T.U	16		5.3	4.6			6.35	4.6	16	8.2
Conductivity (umho/cm)	260		240	242			482	240	499	344.6
pH			8.7	7.4			7.6	7.4	8.7	7.8
Total Organic Carbon mg/l	5.4		7.1	7.4			10.7	5.4	10.7	7.7
Total Nitrogen mg/l	0.57		0.79	0.8	0.69		1.09	0.57	1.09	0.8
Nitrate & Nitrite mg/l	<.05		<.05		0.05		0.03	0.03	0.05	0.027
Potassium mg/l	1.8		2				2.8	1.8	2.8	2.3
Calcium mg/l	18		16				22.4	16	24	20.1
Magnesium mg/l	2.5		2.5				3.4	2.5	3.4	2.9
Hardness mg/l	56		50.2				69.9	50.2	72.6	62.2
Sulfate mg/l	16		11				17	11	17	14.0
Fluoride mg/l	0.1		<.01					0.1	0.1	0.008
Silica, reactive mg/l	3.2		3.7				7.9	3	7.9	4.5
Ammonia (as N) mg/l	<.05		<.05				0.23	0.23	0.31	0.148
Total Dissolved Solids mg/l	161		133					133	161	147.0
Mercury ug/l			<1.							
Aluminum mg/l	0.13		0.1				0.023	0.01	0.13	0.1
Arsenic mg/l	<.005									
Iron mg/l	0.18						0.076	0.076	0.18	0.1
Manganese mg/l	0.16						0.068	0.068	0.49	0.2
Lead mg/l	<.002						<.002	<.002		
Copper mg/l	<.01						0.01	0.01	0.01	0.0
Zinc mg/l	<.01									

BLAIR LAKE WATER QUALITY MONITORING PROGRAM - SAMPLING RESULTS - STATION 3

- 1.5M from bottom

Chlorophyll A mg/m3	81.5	132
Total Phosphorus mg/L	0.056	0.06
Ortho Phosphorus mg/L	0.005	0.005

APPENDIX A STATION 8

PARAMETERS	August 1982	August 1983	August 1984	August 1985	August 22 1990	July 29, 2004	Sept 16, 2004	MIN	MAX	MEAN
Sodium mg/l										
Alkalinity mg/l						53	50	50	53	52
Chloride mg/l										
Ortho-Phosphorous (as P) mg/l						0.005	0.004	0.004	0.005	0
Suspended Solids mg/l		12				9	<1.5	9	12	11
Colour T.C.U.										
Turbidity J.T.U						494	489	489	494	492
Conductivity (umho/cm)						7.7	7.5	7.5	7.7	8
pH										
Total Organic Carbon mg/l										
Total Phosphorous		0.047				0.076	0.098	0.047	0.098	0.074
Total Nitrogen mg/l						1.4	0.96	0.96	1.4	1
Chlorophyll a mg/cubic m		20.9				155	63.2	20.9	155	80
Nitrate & Nitrite mg/l						<.01	0.04	0.04	0.04	0.023
Potassium mg/l										
Calcium mg/l										
Magnesium mg/l										
Hardness mg/l										
Sulfate mg/l										
Fluoride mg/l										
Silica, reactive mg/l										
Ammonia (as N) mg/l										
Total Dissolved Solids mg/l					0.2	0.27	0.2	0.2	0.27	0.22
Mercury ug/l										
Aluminum mg/l										
Arsenic mg/l										
Iron mg/l										
Manganese mg/l										
Lead mg/l										
Copper mg/l										
Zinc mg/l										
Transparency (SD in meters)						0.4				0.400

APPENDIX B STATION 5

BLAIR LAKE WATER QUALITY MONITORING PROGRAM - SAMPLING RESULTS - STATION 5

PARAMETERS	August 1982	August 1983	August 1984	August 1985	August 22 1990	July 29, 2004	Sept 16, 2004	MIN	MAX	MEAN
Sodium mg/l	72	37	40			64.5	67.6	37	72	56.2
Alkalinity mg/l	122	85	62			134	150	62	150	110.6
Chloride mg/l	101	56	58			89	85	56	101	77.8
Ortho-Phosphorous (as P) mg/l	0.07	0.04	0.08			0.008	0.01	0.008	0.08	0.036
Suspended Solids mg/l	2.8	2.3	2.5	<0.02				2.3	2.8	2.5
Colour T.C.U.	20	25	60			19	16	16	60	28.0
Turbidity J.T.U	2.5	1.5	3.3			2.16	1.18	1.18	3.3	2.1
Conductivity (umho/cm)	610	410	401			610	592	401	610	524.6
pH	8.2	7.9	7.5			7.8	8.1	7.5	8.2	7.9
Total Organic Carbon mg/l	3.7	5.1	10			5.4	5.9	3.7	10	6.0
Total Phosphorous	0.03	0.046	0.09	0.023		0.097	0.047	0.023	0.097	0.056
Total Nitrogen mg/l	0.58	0.82	1.9	0.72		0.85	0.83	0.58	1.9	1.0
Chlorophyll a mg/cubic m	2.9			0.47				2.9	2.9	2.9
Nitrate & Nitrite mg/l	0.34	0.36				0.77	0.9	0.34	0.9	0.6
Potassium mg/l	3.4	3.7				2.7	2.5	2.5	3.7	3.1
Calcium mg/l	40	31				45.6	44.6	31	45.6	40.3
Magnesium mg/l	6	4.3				7.1	8.6	4.3	8.6	6.5
Hardness mg/l	124	95.1				143	146.7	95.1	146.7	127.2
Sulfate mg/l	35	17				25	28	17	35	26.3
Fluoride mg/l	0.2	0.1						0.1	0.2	0.2
Silica, reactive mg/l	8.1	8.6				12	13	8.1	13	10.4
Ammonia (as N) mg/l	<0.05	<0.05				0.04	0.04	0.04	0.04	0.033
Total Dissolved Solids mg/l	354	221						221	354	287.5
Mercury ug/l	<1.0	<1.0								
Aluminum mg/l	0.07	<0.05				0.016	0.01	0.01	0.07	0.030
Arsenic mg/l	<0.005									
Iron mg/l	0.23					0.373	0.315	0.23	0.373	0.3
Manganese mg/l	0.44					0.462	0.492	0.44	0.492	0.5
Lead mg/l	<0.002					<0.002	<0.002	0.492	0.492	0.5
Copper mg/l	<0.01									
Zinc mg/l	<0.01					0.006	0.011	0.006	0.011	0.009
Transparency (SD in meters)										

APPENDIX B STATION 6

BLAIR LAKE WATER QUALITY MONITORING PROGRAM - SAMPLING RESULTS - STATION 6

PARAMETERS	August 1982	August 1983	August 1984	August 1985	August 22 1990	July 29, 2004	Sept 16, 2004	MIN	MAX	MEAN
Sodium mg/l		24	31			129.3	96.8	24	129.3	70.28
Alkalinity mg/l		62	54			112	103	54	112	82.75
Chloride mg/l		39	51			229	173	39	229	123.00
Ortho-Phosphorous (as P) mg/l		<0.2	0.02	0.02		0.006	0.005	0.005	0.02	0.015
Suspended Solids mg/l		1.3	1.3					1.3	1.3	1.30
Colour T.C.U.		25	50			13	20	13	50	27.00
Turbidity J.T.U		1.7	1.6			1.5	0.86	0.86	1.7	1.42
Conductivity (umho/cm)		280	312			996	766	280	996	588.50
pH		7.6	7.2			7.6	7.8	7.2	7.8	7.55
Total Organic Carbon mg/l		6.3	8.9			10.2	9.7	6.3	10.2	8.78
Total Phosphorous		0.03	0.023	0.013		0.066	0.034	0.013	0.066	0.03
Total Nitrogen mg/l		0.66	0.65	1.2		1.26	0.87	0.65	1.26	0.93
Chlorophyll a mg/cubic m				0.68		0.79	0.71	0.3	0.79	0.62
Nitrate & Nitrite mg/l		0.3				2.7	3	1.4	3	2.37
Potassium mg/l		1.4								
Calcium mg/l		25				59.8	52.6	25	59.8	45.80
Magnesium mg/l		2.2				5.1	4.7	2.2	5.1	4.00
Hardness mg/l		71.5				170.2	150.6	71.5	170.2	130.77
Sulfate mg/l		6.9				7.7	<1.00	6.9	7.7	5.03
Fluoride mg/l		0.1						0.1	0.1	0.10
Silica, reactive mg/l		5.3				7.8	8.9	5.3	8.9	7.33
Ammonia (as N) mg/l		<.05				0.24	0.04	0.04	0.24	0.101
Total Dissolved Solids mg/l		154						154	154	154.00
Mercury ug/l		<1.0								
Aluminum mg/l		0.06				14	10	0.06	14	8.02
Arsenic mg/l										
Iron mg/l						0.246	0.11	0.11	0.246	0.18
Manganese mg/l						0.911	0.054	0.054	0.911	0.48
Lead mg/l										
Copper mg/l						<.002	<.002			
Zinc mg/l						<.002	0.008	0.008	0.008	0.005
Transparency (SD in meters)										

APPENDIX B STATION 7

BLAIR LAKE WATER QUALITY MONITORING PROGRAM - SAMPLING RESULTS - STATION 7										
PARAMETERS	August 1982	August 1983	August 1984	August 1985	August 22 1990	July 29, 2004	Sept 16, 2004	MIN	MAX	MEAN
Sodium mg/l						79.6	128.8	79.6	128.8	104.20
Alkalinity mg/l						126	148	126	148	137.00
Chloride mg/l						130	201	130	201	165.50
Ortho-Phosphorous (as P) mg/l				0.02		0.008	0.007	0.007	0.02	0.01
Suspended Solids mg/l						30	61	30	61	45.50
Colour T.C.U.						2.11	12.4	2.11	12.4	7.26
Turbidity J.T.U						707	961	707	961	834.00
Conductivity (umho/cm)						7.6	7.5	7.5	7.6	7.55
pH						5.7	8	5.7	8	6.85
Total Organic Carbon mg/l				0.05		0.073	0.088	0.05	0.088	0.07
Total Phosphorous				0.016		0.62	0.74	0.016	0.74	0.46
Total Nitrogen mg/l				0.21		0.33	0.24	0.21	0.33	0.26
Chlorophyll a mg/cubic m						2.2	3.1	2.2	3.1	2.65
Nitrate & Nitrite mg/l						46.4	50.8	46.4	50.8	48.60
Potassium mg/l						5	5.6	5	5.6	5.30
Calcium mg/l						136.3	149.8	136.3	149.8	143.05
Magnesium mg/l						11	10	10	11	10.50
Hardness mg/l										
Sulfate mg/l										
Fluoride mg/l						9.2	9.4	9.2	9.4	9.30
Silica, reactive mg/l						0.13	0.5	0.13	0.5	0.32
Ammonia (as N) mg/l										
Total Dissolved Solids mg/l										
Mercury ug/l						0.011	0.016	0.011	0.016	0.01
Aluminum mg/l										
Arsenic mg/l						0.762	1.679	0.762	1.679	1.22
Iron mg/l						1.522	4.433	1.522	4.433	2.98
Manganese mg/l										
Lead mg/l						<.002	<.002	<.002	<.002	0.004
Copper mg/l						<.002	<.002	<.002	<.002	0.007
Zinc mg/l										
Transparency (SD in meters)										