ENVIRONMENT CANADA
CONSERVATION AND PROTECTION
ENVIRONMENTAL PROTECTION
PACIFIC AND YUKON REGION
NORTH VANCOUVER, B.C.

DRAFT

WATER QUALITY AND SEDIMENT ANALYSIS EQUITY SILVER MINES DATA FROM 1988, 1989, AND 1990 SURVEYS

REGIONAL PROGRAM REPORT: 92-02

by

Benoit Godin

MARCH 1992

ABSTRACT

Environmental Protection conducted monitoring programs on Goosly Lake in 1988, 1989, and 1990 to determine the impact of Equity Silver mine discharges. Multiple approaches were used including sediment coring and dating, sediment bioassays, sequential extractions, water quality measurements, complexing capacity, fish tissue analysis, and biological surveys of benthic invertebrates and zooplankton.

Overall the quality of the lake has improved from previous surveys (Godin, 1988). Sediment chemistry showed changes related to treated AMD discharges to Buck Creek. The lake showed high potential of recovery from contamination due to a sedimentation rate evaluated at 10.6 mm/year.

Sediment techniques and peamouth chub tissues may provide adequate monitoring tools to track impacts in the future when the mine is decommissioned.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the support received from Gerry Mitchell, Vivian Chamberlain, and Isobel Booth in preparing for and carrying out these surveys. Peter Kilion diligently fabricated the sediment traps and the core extruder. Bernie Dutka and Trevor Reynoldson of NWRI were kind enough to perform the sediment bioassays. Chris Millard spend a lot of time developing sequential extraction capability at the EP chemistry lab. Mike Hagen's help was invaluable in producing the final report. I thank you all.

TABLE OF CONTENTS

	PAGE
ABSTRACT	i
RESUME	ii
TABLE OF CONTENTS	iii
List of Tables	v
List of Figures	vii
1.0 INTRODUCTION	1
2.0 DESCRIPTION OF THE STUDY AREA	2
3.0 MATERIAL AND METHODS	5
3.1 Water	5
3.1.1 Immediates	5
3.1.2 Metals	5
3.1.3 Copper Complexing Capacity	6
3.2 Sediments	6
3.2.1 Collection	6
3.2.2 Analysis	7
3.2.2.1 Metal content	7
3.2.2.2 Sediment extractions	8
3.2.2.3 Radionuclear	9
3.3 Bioassays	10
3.3.1 Daphnia Magna	10
3.3.2 Ceriodaphnia Dubia	10
3.3.3 Agar Spot Plate	11
3.3.4 Toxi-chromotest	11
3.3.5 Spirillum volutans	11
3.3.6 Microtox	12
3.3.7 Mutatox	12
3.3.8 ATP-TOX System	12
3.3.9 Algal-ATP	13
3.3.10 Chirononus Tentans	13
3.4 Invertebrates	13
3.4.1 Benthic Invertebrates	13
3.4.2 Zooplankton	14
3.5 Fish	14
3.6 Quality Control	14
3.7 Statistics	14
4.0 RESULTS AND DISCUSSION	17
4.1 Water	17
4.1.1 May 26 - 27, 1988	17
4.1.2 June 22 - 23, 1988	25

TABLE OF CONTENTS (Continued)

4.1.3	June 30 - July 2, 1989	38
4.1.4	June 15 - 17, 1990	43
4.2	Sediments	43
4.2.1	Lake Surface Sediment Collection	43
4.2.2	Buck Creek Sediment Collection	55
4.2.3	Goosly Lake Core Profile	58
4.2.4	Lead-210	71
4.2.5	Sequential Extraction	75
4.3	Copper Complexing Capacity	84
4.4	Bioassays	86
4.5	Benthic Invertebrates	86
4.6	Zooplankton	90
4.7	Fish Tissue Analysis	93
4.8	Environmental Risk Assessment	95
5.0	**CONCLUSION**	106
REFERENCES		108
ACKNOWLEDGMENTS		111

LIST OF TABLES

TABLE		PAGE
1	Sample Station Description	2
2	Water Quality - Goosly Lake - May 26 - 27, 1988	18
3	Goosly Lake Temperature Conductivity Profile - May 26 - 27, 1988	22
4	Water Quality - Goosly Lake - June 22 - 23, 1988	26
5	Goosly Lake Temperature Conductivity Profile - June 22-23, 1988	30
6	Water Quality - Buck Creek - June 22 - 23, 1988	34
7	Water Quality - Buck Creek System - June 30, 1988	39
8	Goosly Lake Temperature Conductivity - Profile - June 30, 1988	38
9	Water Quality - Buck Creek System - June 16, 1990	44
10	Goosly Lake Temperature Conductivity Profile - June 16, 1990	49
11	Sediment Quality - Goosly Lake - June 22, 1988	50
12	Sediment Quality - Buck Creek System - July 2, 1989	51
13	Sediment Quality - Goosly Lake - June 16, 1990	53
14	Sediment Quality - Buck Creek - June 23, 1988	56
15	Sediment Core Profile - Station 12 - May 23, 1988	59
16	Goosly Lake Lead-210 Analysis in Sediment Core Sample	74
17	Sequential Extractions - Goosly Lake	77
18	Percent Non-desorbable Cadmium and Zinc on River Suspended Matter After Treatment With NaCl Solution of Seawater Concentration	83
19	Sulphate and Calcium Concentration in Goosly Lake	85
20	Copper Complexing Capacity for Buck Creek System - 1989	85
21	Sediment Bioassay Results	87
22	Summary of Benthic Invertebrates - 1989	88
23	Benthic Invertebrates - Goosly Lake - June 16 -18, 1990	89
24	Percent Similarity Index of Benthic Invertebrates - Goosly Lake - 1990	90
25	Zooplankton - Goosly Lake - June 16 - 18, 1990	91
26	Fish Characteristics and Mercury Muscle Analysis - Goosly Lake - June 17, 1990	94
27	Lipid Content in Fish Muscle - Goosly Lake - June 17, 1990	95
28	Fish Muscle Metal Analysis - Goosly Lake - June 17, 1990	96
29	Fish Gills Metal Analysis - Goosly Lake - June 17, 1990	98
30	Fish Liver Metal Analysis - Goosly Lake - June 17, 1990	100
31	Fish Kidney Metal Analysis - Goosly Lake - June 17, 1990	101
32	Goosly Lake Metal Concentration Factor	102
33	Equity Mine AMD Pump Records	103
34	Goosly Lake Risk Factors	104

LIST OF FIGURES

FIGURE		PAGE
1	Sampling Locations in Buck Creek System	7
2	Goosly Lake Sampling Locations	9
3	Goosly Lake Sediment Profile - Arsenic	61
4	Goosly Lake Sediment Profile - Cadmium	62
5	Goosly Lake Sediment Profile - Chromium	63
6	Goosly Lake Sediment Profile - Copper	64
7	Goosly Lake Sediment Profile - Lead	65
8	Goosly Lake Sediment Profile - Manganese	66
9	Goosly Lake Sediment Profile - Mercury	67
10	Goosly Lake Sediment Profile - Silicon	68
11	Goosly Lake Sediment Profile - Zinc	69
12	Lead-210 Distribution in Goosly Lake Sediment Profile	72
13	Percent Moisture in Goosly Lake Sediment Profile	73
14	Sequential Extraction - Goosly Lake - Arsenic	78
15	Sequential Extraction - Goosly Lake - Cadmium	79
16	Sequential Extraction - Goosly Lake - Copper	80
17	Sequential Extraction - Goosly Lake - Lead	81
18	Sequential Extraction - Goosly Lake - Zinc	82

1.0 INTRODUCTION

Equity Silver Mine is located approximately 33 km southeast of Houston, B.C. The mine began production in September 1980. In November 1981 it was determined that waste rock at the mine site was generating acid. The company constructed an acid mine drainage collection system and has treated the water since that time.

Environmental Protection undertook a water and sediment monitoring program to evaluate the impact of the mining operation on Goosly Lake in the Buck Creek system. The sedimentological approach was used in 1987 and pursued in 1988, 1989, and 1990.

2.0 DESCRIPTION OF THE STUDY AREA

The Equity mine is near the headwaters of Foxy Creek and Bessemer Creek, the latter being a tributary to Buck Creek which flows into Goosly Lake and continues until it joins the Bulkley River at Houston (Figure 1).

Water quality and sediment stations were visited May 26-27, 1988, June 22-23, 1988, June 30 to July 2, 1990 [handwritten correction: 89], and June 16-18, 1990. A variety of monitoring activities were undertaken at different stations during the visits (Table 1, Figure 2).

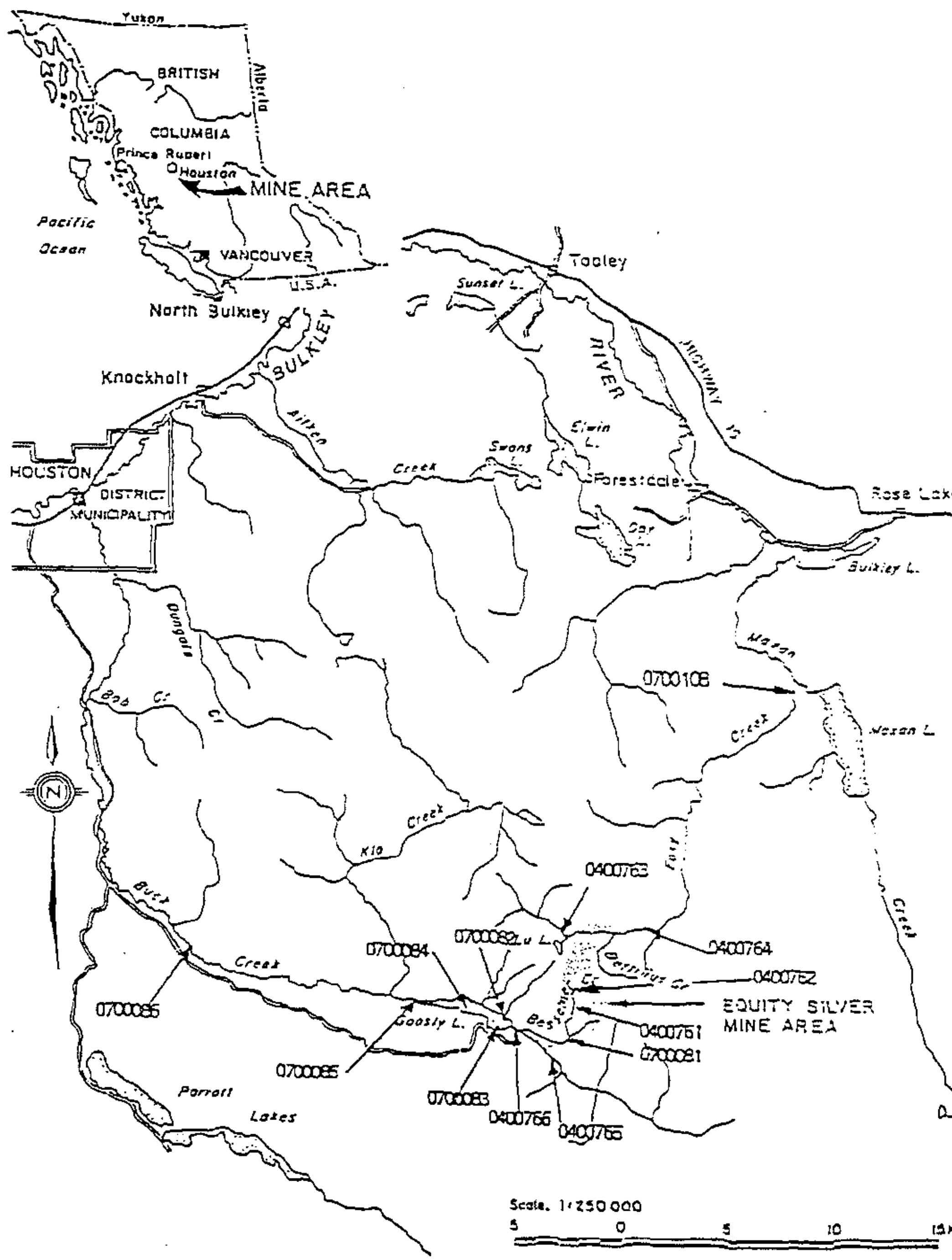
TABLE 1: SAMPLE STATION DESCRIPTION

Station	Description	Study Performed			
		May 88	June 88	Jun/Jul 89	June 90
1	Buck Creek u/s Bessemer	-	W	W,S	W,S
2	Siltcheck dam	-	W	W,S,B	W
3	Buck Creek at Goosly Lk.	-	W	W,S	W,S
4	Goosly Lake	W	W	S,Z,I	-
5	Goosly Lake	W	W,S	-	-
6	Goosly Lake	W	W	-	-
7	Goosly Lake	W	W,S	-	S
8	Goosly Lake	W	W,S	S,Z,B,I	W,S,Z,B,I
9	Goosly Lake	W	W,S	S,Z,I	-
10	Goosly Lake	W	W	Z,I	S
11	Goosly Lake	W	W,S	-	W,S,Z,B,I
12	Goosly Lake	C	-	W,S,Z,R,I	W,S,Z,B,I
13	Buck Creek d/s Goosly Lk.	-	W	W,S	W,S

W = Water samples
S = Sediment samples
B = Sediment bioassay
Z = Zooplankton samples
C = Core profile
R = Radionuclide profile
I = Benthic invertebrate samples

EQUITY SILVER MINES LIMITED

REGIONAL MAP WITH SAMPLE LOCATIONS



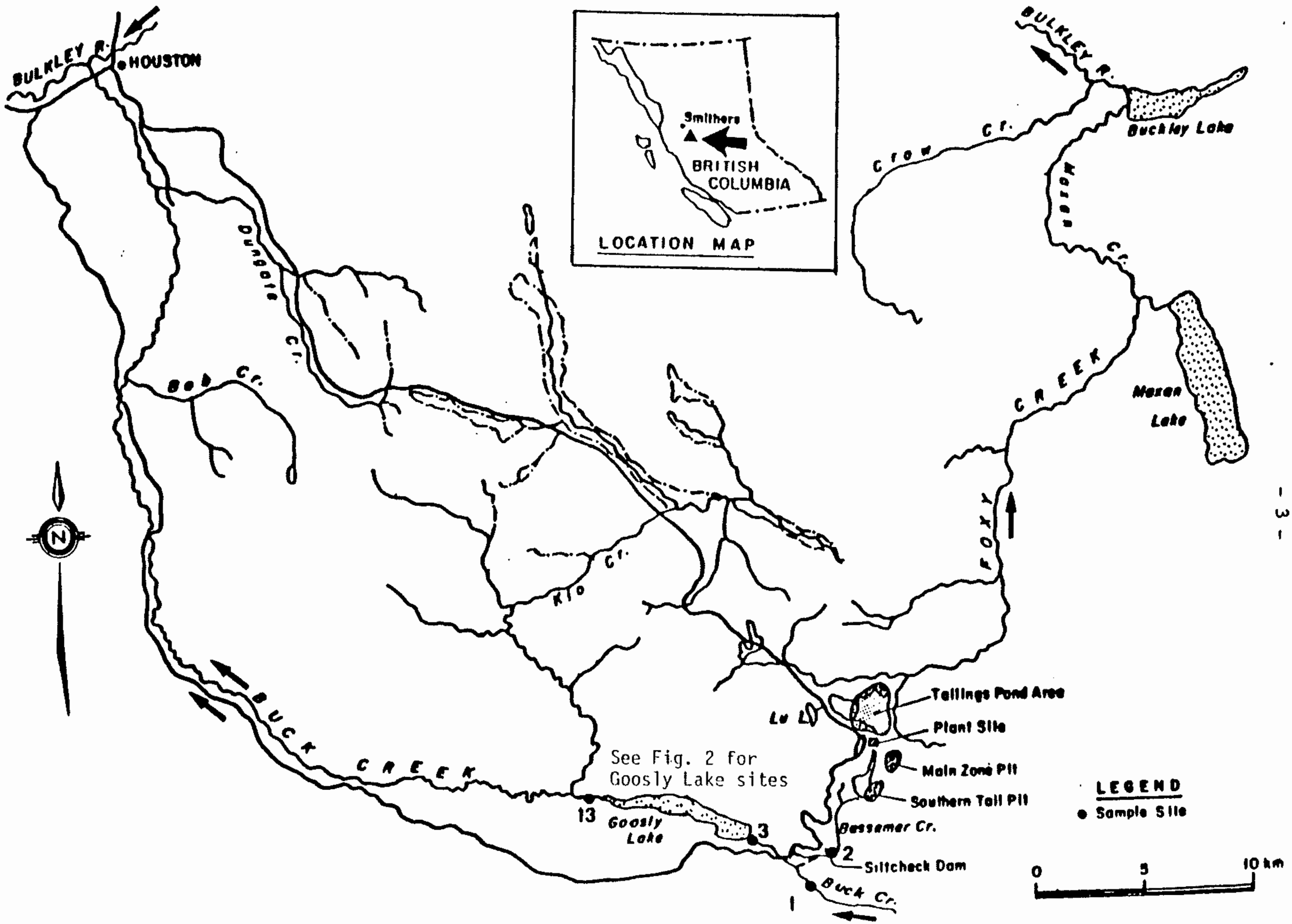


FIGURE 1: SAMPLING STATION LOCATIONS IN BUCK CREEK SYSTEM

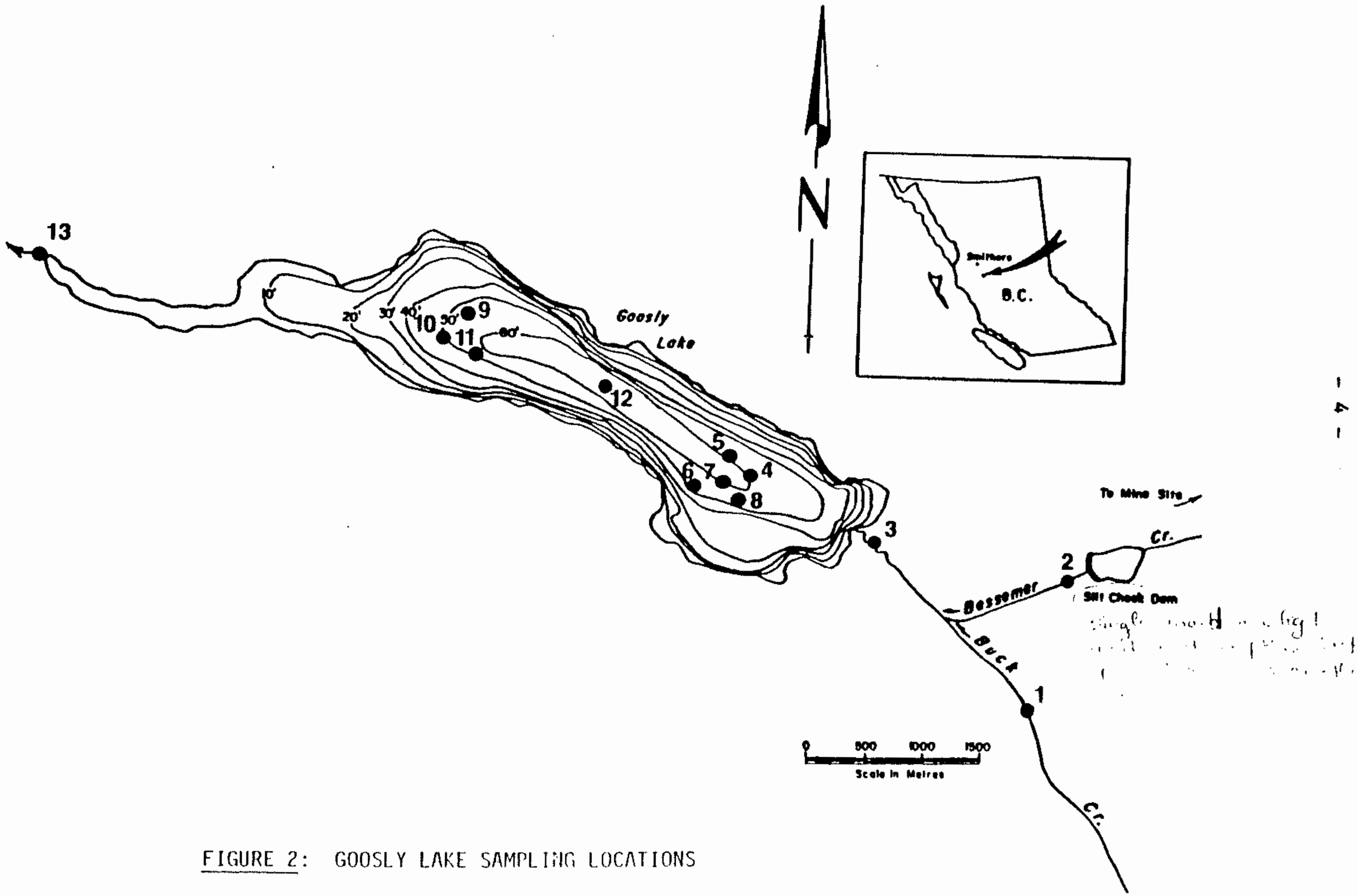


FIGURE 2: GOOSLY LAKE SAMPLING LOCATIONS

3.0 MATERIALS AND METHODS

3.1 Water

Water samples collected in Buck Creek on each sampling date consisted of replicated samples. The lake samples were collected one metre below the surface, and one metre above the bottom using a Van Dorn bottle. Samples near the thermocline were sampled either immediately above and below the thermocline (in the case of a 4-samples-per-watercolumn design), or in the thermocline (in the case of 3-samples-perwater-column design).

Lake profiles were performed at several stations using a Hydrolab digital 4041 indicator unit and a 4021 Sonde unit. Conductivity, temperature, and pH were recorded.

3.1.1 **Immediates.** Water quality analysis included alkalinity, pH, nitrites, nitrates, total residues, filterable residues, non-filterable residues, and sulphates; these parameters were labeled as immediates. Samples were collected using one litre polyethylene bottles and kept cool until analysed. The organic and inorganic carbon samples were collected in acid washed glass jars and preserved with a few drops of concentrated hydrochloric acid. The dissolved fraction of these two parameters were filtered within 24 hours of collection using a 0.45 µm cellulose nitrate filter.

3.1.2 **Metals.** Total metal samples were collected in a 100 ml acid washed polyethylene sample bottle and preserved with 0.5 ml of nitric acid. Dissolved metal samples were filtered the same day through a 0.45 µm cellulose nitrate filter into a 100 ml polyethylene bottle and preserved with 0.5 ml of nitric acid. Total and dissolved metals were analysed by Inductively Coupled Argon Plasma (ICAP) Emission Spectroscopy which gave a reading of twenty-six metals. The detection limits for trace metals analysed on ICAP were (in mg/L): aluminum, <0.05; antimony, <0.05; arsenic, <0.05; barium, <0.001; beryllium, <0.001; boron, <0.01; cadmium, <0.005; calcium, <0.1; cobalt, <0.005; copper, <0.005; iron, <0.005; lead, <0.05; magnesium, <0.1; manganese, <0.001; molybdenum, <0.01; nickel, <0.02; phosphorus, <0.1; selenium, <0.5; silicon, <0.05; sodium, <0.01; tin, <0.05; strontium, <0.01; titanium, <0.002; vanadium, <0.01; and zinc, <0.002. Cadmium, copper, and lead samples were re-analysed with a graphite furnace when the values were below twice the detection limit of the ICAP procedure. The graphite furnace detection limit for cadmium, copper and lead was <0.0001, <0.0005, and

<0.0005 mg/L, respectively. Hardness was determined from the dissolved metal sample.

Antimony, arsenic, boron, beryllium, cobalt, molybdenum, nickel, titanium, and vanadium were not included in the data table due to levels near or below the detection limit. Strontium was not included in the analysis due to the large amount of contamination.

All analyses were performed by the Environmental Protection laboratory in West Vancouver in accordance with the Environment Canada, Pacific Region, Laboratory Manual (Anon., 1979).

3.1.3 Copper Complexing Capacity. Complexing capacity samples were collected in August 1990, and analysed by CBR International. The complexing capacity of the organic ligands to bind copper were determined indirectly by voltametry using a polarograph. The organic ligands were titrated with increased quantities of Cu^{2+}. Such titration curves show a break in the gradient of the curve that corresponds to the saturation of the organic ligands to Cu^{2+}. Calculations of complexing capacity and conditional stability constants were performed using the method described by Rubic (1982).

3.2 Sediments

3.2.2 Collection. Lake sediments were collected during the June 1988 survey using a Plexiglas sediment trap with a 45 cm internal diameter and 5 cm height based on a design described by Hσkanson (1976). Four lead-weighted arms were attached to the bottom of the trap to add stability and prevent tipping. The trap was left in place for four weeks. A Plexiglas lid was lowered on a stainless steel cable fixed in the middle of the trap during retrieval to avoid sample loss.

Lake bottom metal profiles were obtained by lowering a Phleger corer into the sediments. After corer penetration of about 35-40 cm, visual examination of the transparent core liner showed no evident disturbance of the top sediment with no turbidity above the sediment-water interface. Sediment was extruded and fractioned at every centimetre based on a modification of the close-interval fractionator described by Fast and Wetzel (1974). Sediment fractions were pushed above a Plexiglas plate by a plastic rod fitted with a rubber bung. The extruded sediment was cut off and contained by a sliding plastic ring and deposited into the sampling bag. The plate and ring were rinsed in water prior to each section.

Surface lake sediments from the June 1989 and 1990 surveys were collected using an Eckman dredge.

Four creek sediment samples were collected at each site using a clean acrylic tube with a 4.6 cm internal diameter pushed into the streambed about 6-8 cm. All sediment samples were transferred into Kraft soil sample envelopes, contained in a Whirl-pack bag, and kept cool until analysed.

3.2.2 Analysis.

3.2.2.1 Metal content. Sediment samples were air dried, sieved to <150 µm (except for sediment from traps which were sieved to <63 µm), digested with aqua regia, and analysed for heavy metals using ICAP. A portion of the sediments were also ignited at 500°C in a muffle furnace. The loss of weight was reported as volatile residue and the remainder as fixed residue. Trap samples were also analysed for total nitrogen which was determined by autoclaving the sediments with potassium persulphate in a basic environment. The process converts all forms of nitrogen into nitrate. The results were obtained with a colourimetric method. Five samples were submitted for nitrogen Kjeldahl analysis.

3.2.2.2 Sediment extractions. Samples were air dried, sieved to <150 µm, and rolled to homogenise. The samples were weighed into 50 ml centrifuge tubes and subjected to a sequential leaching procedure designed to partition trace metals into the following fractions:

1) F(a): Exchangeable metals. The sediment sample is extracted with 1M $MgCl_2$ initially at pH 7 at room temperature for one hour on a wrist action shaker.
2) F(b): Metals bound to carbonates or specifically adsorbed. The residue from (a) is leached with 1M sodium acetate adjusted to pH 5 with acetic acid at room temperature for five hours on a wrist action shaker.
3) F(c): Metals bound to Fe-Mn oxides. The residue from (b) is extracted at 96°C for six hours with 0.04M $NH_4OH.HCl$ in 25% (vol/vol) acetic acid.
4) F(d): Metals bound to organic matter and sulphides. The residue from (c) is extracted at 85°C for five hours with 0.02M HNO_3 and 30% H_2O_2 adjusted to pH 2 with HNO_3 and then at room temperature with 3.2M NH_4OAc in 20% (vol/vol) HNO3 for 30 minutes on a wrist action shaker.

5) F(e): Residual metals. The original dried samples are weighed in Teflon digestion vessels and digested with HNO_3 and HCl in a microwave oven, resulting in a total fraction (MT). The residual F(e) is calculated via F(e) = MT - [F(a) + F(b) + F(c) + F(d)].

Analysis was performed via Inductively Coupled Argon Plasma (ICAP) Emission Spectroscopy.

3.2.2.3 Radionuclear. The radionuclear analysis was provided by Chemex Consultants, Ltd.

- Principle: Lead-210 is typically determined by measuring the beta emission of its daughter, bismuth-210, which is isolated by a radiochemical separation. The direct beta emission of lead-210 is feeble and difficult to detect; by contrast, that from bismuth-210 has a higher energy and is easier to detect. The bismuth-210 activity is measured with a beta detector and compared with the activity of standards carried through the same procedure.

- Experimental: One gram subsamples of dry soil or sediment were digested with a mixture of hot concentrated nitric, perchloric, and hydrofluoric acids and evaporated to dryness in a Teflon dish. The salt residues were dissolved in 2M hydrochloric acid, a lead and bismuth carrier solution was added, and the bismuth-210 was extracted into chloroform with diethyl-ammonium dithiocarbamate. An aliquot of the extract was removed in order to test the efficiency of the extraction by atomic absorption spectroscopy. The remaining bismuth was precipitated as mixed hydroxide and oxychloride salts redissolved and purified by precipitation of bismuth oxychloride. The precipitate was collected on a 0.45 µm membrane filter, air-dried, weighed, mounted on a ring and disc assembly, covered with aluminum foil, and beta-counted after 24 hours. The aluminum foil screened out any weak beta emissions from lead-210 while allowing the more energetic bismuth-210 particles to pass through. The storage period of 24 hours allowed for the decay of other bismuth isotopes (211, 212, 214) which may have been present.

The activity of samples was compared with the activity of standards carried through the same procedure. Counting periods were 100 minutes and the sample activity was reported, together with an uncertainty value which reflected the fact that the measurement process is a statistical process and, therefore, has an uncertainty value associated with it. The absolute detection limit of the method is normally 0.05 Bq but may vary slightly due to such factors as sample weight, extraction efficiency, detector efficiency or detector background activity.

3.3 Bioassays

Sediments for bioassay were collected with an Eckman dredge. Two samples were collected in 1989, one from the siltcheck dam and another from the Goosly Lake bottom. Sediments were kept cool and sent to the Environment Canada, Inland Waters Laboratory in Burlington, Ontario, for analysis.

The 1989 sediments were extracted with Milli-Q reagent grade water (4 cartridge system-1, Super C carbon cartridge, Ion-Ex™ cartridge, Organet-Q^{r} cartridge and a Milli-Stak™ filter with a glass distilled water feed) in a 1:1 ratio (Vol:Wt) and shaken vigorously for 3 minutes. The mixture was centrifuged at 500 rpm in a refrigerated centrifuge for 10 minutes. The supernatant was used in the toxicity screening tests. Nine tests were performed on these sediments (Dutka et al., 1987).

In 1990, three samples were collected from Goosly Lake for a Chironomus tentans 25-day emergence test. Samples were sent to Burlington for analysis.

3.3.1 Daphnia magna. The Daphnia magna used in these tests is the largest of the Daphnia, often reaching 5 mm in size. The neonates (first-instar young) are 0.8 and 1.0 mm long and can be observed by eye. This stage is the one most commonly used for tolerance studies. Tests are performed on neonate Daphnia that have been released from the mother's brood chamber during the previous 24 hours. In the test, ten neonates are used for each dilution of sample to be tested. The neonate Daphnia are observed at 1 hour, 4 hours, 24 hours, and 48 hours, and the number of dead animals are recorded. A 24-hour or 48-hour LC_{50} or EC_{50} value is then derived from the pattern of deaths observed.

3.3.2 Ceriodaphnia dubia. The cladoceran Ceriodaphnia dubia was used to evaluate the chronic toxicity of the samples. In this test, six beakers of approximately 30 ml volume were used for each sample dilution and control, with one animal per beaker. Tests were performed with young animals that were as similar in age as possible (8 hrs. maximum). On the 3rd, 5th, and 7th day of the test, the young were counted and discarded. During the test period the animals were fed daily. At the end of the test the number of young per original adult and the number of broods per adult were compared to those obtained in the control sample. An average of 2.5 broods per adult in the controls has been used as the end point in some testing procedures (Rao, 1988).

3.3.3 **Agar Spot Plate**. This is a simple, rapid procedure for finding the toxicity of both water-soluble and -insoluble compounds by use of a direct agar-diffusion assay. The procedure uses a non-toxic carrier system for DMSO-glycerol extracted samples and a 30°C incubation temperature. Zones of inhibition are noted. The bacterial species used to provide the background lawn is Bacillus cereus and the sample (water or DMSO-glycerol extract) is spotted onto the seeded agar plate. Results can be obtained in three to four hours or overnight as required (Dutka, 1988).

3.3.4 **Toxi-chromotest**. This is a fairly rapid (2-3 hr) bacterial colourimetric assay in kit form which can be used to test for toxicant activity in water and sediment extracts. The assay is based on the ability of substances (toxicants) to inhibit the de nova synthesis of an inducible enzyme, beta galactosidase, in a highly permeable mutant of E. coli. The sensitivity of the test is enhanced by exposing the bacteria to stressing conditions (provided by kit materials) after which they are rehydrated in a cocktail containing a specific inducer of beta galactosidase and essential factors required for the recovery of the bacteria from their stressed condition. The activity of the induced enzyme is detected by the hydrolysis of a chromogenic substrate. Toxic materials interfere with the recovery process and thus with the synthesis of the enzyme and the colour reaction.

3.3.5 **Spirillum volutans**. The organism S. volutans is a large aquatic bacterium which is readily visible under low magnification. It has flagella fascicles at each end which, under normal conditions, form oriented, revolving cones allowing the bacterium to move forward and reverse directions at will. During the reversing process the polar fascicles reorient simultaneously. To perform the test, S. volutans is added to a volume of the sample and the mobility of the organisms is observed with a microscope. If the sample is toxic but at a non-lethal level, S. volutans loses coordination as both fascicles try to assume the head or tail orientation, thus preventing normal bacterial motion.

3.3.6 **Microtox**. Microbics Corporation has devised a test for acute levels of toxicants in water or sediment extracts in which specialized strains of luminescent bacteria (Photobacterium phosphoreum) are used as the bioassay organism. This test is functional because the metabolism of the luminescent bacteria is influenced by low levels of toxicants and, occasionally, stimulants. Any alteration of metabolism affects the intensity of the organism's light output. By sensing these changes in light output, the presence and relative concentration of toxicants can be obtained by establishing the EC^{50} levels from graphed data (EC^{50} being that concentration of toxicant causing a 50% reduction in light from the baseline level).

3.3.7 **Mutatox**. This is a relatively new test, developed by Microbics Corporation, based on the use of a dark mutant strain of Photobacterium phosphoreum, M169, to screen for the presence of genotoxic agents. This test will pick up chemicals which are (a) DNA damaging agents, (b) DNA intercalating agents, (c) direct mutagens which either cause base substitution or are frame shift agents, and (d) DNA synthesis inhibitors. The test procedures are similar to those followed in the Microtox test with incubation of M169 cells, cell media, and sample at 22 ± 2°C. Light level is read after 18 ± 1 hour contact and compared to negative controls (dilution water, solvent concentration used, and sodium azide).

3.3.8 **ATP-TOX System**. The concentration of ATP per bacterial cell remains relatively constant and stable throughout all phases of growth. Thus, bacterial densities can be easily estimated by measuring the ATP content of the test system. When rapidly growing bacterial cells are exposed to toxicants, growth inhibition usually occurs. After several life cycles the toxic effect can be estimated by comparing sample cell growth to the control via ATP content. However, some toxicants not only inhibit bacterial growth but also affect the luciferase activity during ATP determinations. Therefore, the observed light output reduction of the test system is the net result of the inhibition of both bacterial growth and luciferase (called "total inhibition of the ATP-TOX System"). Luciferase activity inhibition can be determined by adding a standard ATP solution, as enzyme substrate, to the sample and to a distilled water control, and measuring the light emission of the enzyme. In our studies, we use E. coli, K-12.PQ37 strain, although any bacterium or mixture of bacteria can be used in this technique.

3.3.9 **Algal-ATP**. The algal-ATP toxicant screening test is based on the inhibition of ATP production in cultures of the green algae Selenastrum capricorutum (Blaise et al., 1984). The ATP content of the stressed Selenastrum is measured fluorescence. The results are reported as a percentage of Relative Light Output (RLO) of the non-stressed controls.

3.3.10 **Chironomus tentans**. Sediments were placed in the test container and covered by a screen to retain adults. The sediment layer was 3 cm deep, overlain by 15 cm of gently aerated water. At the start of the test the larvae were added to the test containers. A food mixture of

Cerophyl, fish food, and distilled water was given to the larvae at the start of the test and again on Day 8, 14, and 18. Adults started to emerge after 20 days. The test was continued for another 5 days to count all emerging adults and to observe any delayed development.

3.4 Invertebrates

3.4.1 Benthic invertebrates. Benthic invertebrates were collected using a 225 cm^2 capacity Eckman dredge. The sample was sieved in the field through a 350 µm mesh screen in 1989 and a 500 µm mesh screen in 1990. The insects were preserved with Kahle's solution: 15 parts ethyl alcohol, 30 parts deionized water, 6 parts 40% buffered formalin, and 1 part glacial acetic acid. Rose bengal was added to help insect sorting.

3.4.2 Zooplankton. Zooplankton samples were collected in triplicate at 3 stations in 1990. The samples consisted of 16-metre vertical tows using a plankton net of 150 µm mesh size. Samples were preserved with Kahle's solution with Rose bengal added, and send for identification.

3.5 Fish

Fish were collected using a gill net of mesh size varying from 2.5 to 10 cm. The net was deployed perpendicular to the south shore of the lake and left for 12 hours. Fish were kept frozen until tissues were removed. Scales were collected and sent to a private laboratory for age identification. Dissecting tools were rinsed in a deionized water/alcohol/deionized water series prior to preparing each fish. Some muscle tissues were send to a private lab for lipid analysis while metal analysis for all tissues were performed at the West Vancouver lab.

3.6 Quality Control

The laboratory personnel performed regular quality control on all water, biota, and sediment analyses. After every tenth sample the laboratory ran a blank sample. After every 40 samples a reagent blank sample was evaluated as well as reference material. A re-evaluation of the samples were performed if measurements were outside of the reference material specified range. All acids used for field preservation and laboratory digestions were "Baker Instra-Analysed" for trace metal analysis. The sediment sample batches included three blanks for each extracted fraction, and three replicates each of the two in-house EP lab reference materials. The number of sample duplicates was at least the square root of the number of samples in the batch.

3.7 Statistics

Means and standard deviations were calculated for all replicated samples. The coefficient of variation was given only for Goosly Lake sediments. Student's t-tests were used for comparisons between stations. The comparisons, for graphical purposes, were performed by one-way ANOVA and use of Tukey's harmonic significant difference multiple comparison plot. The significant difference was established when the probability was <0.05.

Diversity indices were calculated from the bottom fauna data using the Shannon-Weiner diversity index described by Pielou (1975) and modified as follows:

$$\text{Species Diversity } (H') = -\sum_{i=1}^{g} (P_i \log_{10} P_i)$$

Where $P_i = n_i/N$

n_i = total number of individuals in the i^{th} genus

N = total number of individuals identified to genus level

g = total number of genera

The use of individuals identified to genus level instead of to species level results in slightly lower diversity index values.

The diversity of the benthic invertebrate community depends on the number of species and the evenness with which the individuals are apportioned among them. The method of measuring evenness is described by Pielou (1975) and is given by:

$$\text{Evenness } (J') = \frac{H'}{\log g}$$

Where H' = the species diversity

g = the number of genera

Benthic community diversity also depends on the species richness (Boyle et al., 1990). This index is calculated by Margalef's formula:

$$\text{Species Richness } (D) = \frac{S - I}{\ln (I)}$$

where S = total number of species in the community

I = total number of individuals in the community

The benthic communities were also analysed using the Percent similarity index (Psi) as the community index, comparing each station to other stations using the formula described by Brock (1977):

$$Psi = 100 - 0.5 \sum^{k} |a-b|$$

where a and b are, for a given species, the percentage of the total Sample A and B which that species represents.

TABLE 2 (Cont.):

WATER QUALITY - GOOSLY LAKE
May 26-27, 1988

Station (Depth)	TOTICP CU MG/L	TOTGF CU MG/L	DISICP CU MG/L	DISGF CU MG/L	TOTICP FE MG/L	DISICP FE MG/L	TOTHG HG MG/L	TOTICP MG MG/L	DISICP MG MG/L	TOTICP MN MG/L	DISICP MN MG/L	TOTICP MO MG/L	DISICP MO MG/L	TOTICP NA MG/L	DISICP NA MG/L	TOTICP NI MG/L	DISICP NI MG/L
4(1m)	0.007	0.0069	<0.005	0.0056	0.359	0.142	<.00005	4.3	3.8	0.027	0.011	<0.01	<0.01	3.3	3.0	<0.02	<0.02
4(5m)	0.015	0.0051	<0.005	0.0038	0.299	0.125	<.00005	4.5	4.6	0.037	0.172	<0.01	<0.01	3.6	3.6	<0.02	<0.02
4(16m)	<0.005	0.0035	<0.005	0.0038	0.337	0.126	<.00005	5.1	4.1	0.225	0.015	<0.01	<0.01	3.9	3.3	<0.02	<0.02
5(1m)	0.010	0.0094	0.006	0.0041	0.341	0.131	<.00005	4.7	4.1	0.027	0.016	<0.01	<0.01	3.5	3.2	<0.02	<0.02
5(7m)	0.007	0.0061	0.006	0.0050	0.290	0.136	<.00005	4.6	4.0	0.037	0.009	<0.01	<0.01	3.6	3.2	<0.02	<0.02
5(16m)	<0.005	0.0038	<0.005	0.0037	0.352	0.135	<.00005	5.1	4.7	0.229	0.142	<0.01	<0.01	4.0	3.7	<0.02	<0.02
6(1m)	<0.005	0.0047	0.005	0.0044	0.276	0.136	<.00005	4.5	4.0	0.026	0.010	<0.01	<0.01	3.5	3.2	<0.02	<0.02
6(5m)	<0.005	0.0043	<0.005	0.0040	0.307	0.133	<.00005	7.0	4.2	0.045	0.012	<0.01	<0.01	24.5	3.4	<0.02	<0.02
6(15m)	<0.005	0.0036	0.006	0.0043	0.247	0.131	<.00005	4.9	4.7	0.145	0.107	<0.01	<0.01	3.8	3.7	<0.02	<0.02
7(1m)	<0.005	0.0037	<0.005	0.0040	0.298	0.139	<.00005	4.5	4.1	0.026	0.011	<0.01	<0.01	3.5	3.3	<0.02	<0.02
7(5m)	<0.005	0.0043	<0.005	0.0043	0.272	0.127	<.00005	4.6	4.3	0.032	0.013	<0.01	<0.01	3.6	3.4	<0.02	<0.02
7(16m)	<0.005	0.0031	<0.005	0.0043	0.269	0.143	<.00005	5.2	4.9	0.201	0.164	<0.01	<0.01	4.1	3.9	<0.02	<0.02
8(1m)	0.006	0.0041	0.005	0.0043	0.295	0.136	<.00005	4.7	4.1	0.027	0.013	<0.01	<0.01	3.7	3.2	<0.02	<0.02
8(5m)	<0.005	0.0040	<0.005	0.0037	0.239	0.119	<.00005	8.7	4.3	0.035	0.012	<0.01	<0.01	35.3	3.4	<0.02	<0.02
8(13m)	<0.005	0.0029	<0.005	0.0043	0.309	0.130	<.00005	5.1	4.6	0.092	0.056	<0.01	<0.01	3.9	3.7	<0.02	<0.02
9(1m)	0.005	0.0047	<0.005	0.0041	0.286	0.134	<.00005	4.6	4.2	0.028	0.011	<0.01	<0.01	3.7	3.4	<0.02	<0.02
9(10m)	0.008	0.0036	<0.005	0.0039	0.277	0.132	<.00005	4.6	4.3	0.030	0.014	<0.01	<0.01	3.7	3.4	<0.02	<0.02
9(15m)	0.006	0.0029	<0.005	0.0038	0.319	0.131	<.00005	5.0	4.5	0.063	0.037	<0.01	<0.01	4.1	3.5	<0.02	<0.02
10(1m)	0.007	0.0037	<0.005	0.0041	0.335	0.131	<.00005	4.6	4.2	0.027	0.012	<0.01	<0.01	3.7	3.3	<0.02	<0.02
10(10m)	0.006	0.0027	<0.005	0.0039	0.271	0.134	<.00005	4.7	4.3	0.030	0.013	<0.01	<0.01	3.7	3.3	<0.02	<0.02
10(13m)	0.008	0.0031	<0.005	0.0033	0.646	0.171	<.00005	4.8	4.4	0.076	0.061	<0.01	<0.01	3.8	3.5	<0.02	<0.02
11(1m)	<0.005	0.0081	<0.005	0.0043	0.288	0.139	<.00005	4.6	4.3	0.028	0.012	<0.01	<0.01	3.7	3.3	<0.02	<0.02
11(10m)	<0.005	0.0022	<0.005	0.0036	0.270	0.103	<.00005	4.6	4.3	0.029	0.013	<0.01	<0.01	3.6	3.4	<0.02	<0.02
11(14m)	0.006	0.0023	<0.005	0.0036	0.203	0.130	<.00005	4.6	4.6	0.077	0.055	<0.01	<0.01	3.8	3.6	<0.02	<0.02

TABLE 2 (Cont.):

WATER QUALITY - GOOSLY LAKE
May 26-27, 1988

Station (Depth)	TOTICP P MG/L	DISICP P MG/L	TOTICP PB MG/L	TOTGF PB MG/L	DISICP PB MG/L	DISGF PB MG/L	TOTICP SB MG/L	DISGF SB MG/L	TOTICP SI MG/L	DISICP SI MG/L	TOTICP SN MG/L	DISICP SN MG/L	TOTICP SR MG/L	DISICP SR MG/L	TOTICP TI MG/L	DISICP TI MG/L	TOTICP ZN MG/L	DISICP ZN MG/L
4(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	3.96	3.62	<0.05	<0.05	0.258	0.235	0.004	<0.002	0.007	0.006
4(5m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.03	3.91	<0.05	<0.05	0.259	0.266	0.007	<0.002	0.012	0.004
4(16m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.42	3.73	<0.05	<0.05	0.295	0.244	<0.002	<0.002	<0.002	0.005
5(1m)	<0.1	<0.1	<0.05	0.0005	<0.05	<0.0005	<0.05	<0.05	3.95	3.67	<0.05	<0.05	0.265	0.239	0.003	<0.002	0.007	0.003
5(7m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.04	3.70	<0.05	<0.05	0.266	0.239	0.004	<0.002	0.010	0.003
5(16m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.21	4.01	<0.05	<0.05	0.290	0.272	0.002	<0.002	<0.002	0.003
6(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.00	3.68	<0.05	<0.05	0.265	0.239	0.003	<0.002	<0.002	0.003
6(5m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.04	3.81	<0.05	<0.05	0.281	0.250	0.004	<0.002	<0.002	0.003
6(15m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	3.93	4.01	<0.05	<0.05	0.284	0.271	<0.002	<0.002	<0.002	0.003
7(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.07	3.80	<0.05	<0.05	0.268	0.249	0.004	<0.002	<0.002	0.004
7(5m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.03	3.85	<0.05	<0.05	0.268	0.253	0.003	<0.002	0.005	0.003
7(16m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.22	4.15	<0.05	<0.05	0.298	0.284	<0.002	<0.002	<0.002	0.003
8(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.19	3.83	<0.05	<0.05	0.282	0.252	0.003	<0.002	0.002	0.006
8(5m)	<0.1	<0.1	<0.05	0.0010	<0.05	<0.0005	<0.05	<0.05	4.05	3.85	<0.05	<0.05	0.307	0.254	<0.002	<0.002	0.003	0.003
8(13m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.29	4.00	<0.05	<0.05	0.293	0.271	0.004	<0.002	<0.002	0.003
9(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.20	3.89	<0.05	<0.05	0.276	0.256	0.005	<0.002	0.005	0.005
9(10m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.11	3.90	<0.05	<0.05	0.274	0.258	0.004	<0.002	0.003	<0.002
9(15m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.37	3.97	<0.05	<0.05	0.291	0.265	0.007	<0.002	0.009	0.004
10(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.17	3.86	<0.05	<0.05	0.276	0.253	0.004	<0.002	0.004	0.002
10(10m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.27	3.84	<0.05	<0.05	0.278	0.253	0.004	<0.002	<0.002	0.003
10(12m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.71	3.93	<0.05	<0.05	0.278	0.259	0.008	<0.002	<0.002	<0.002
11(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.17	3.93	<0.05	<0.05	0.273	0.259	0.004	<0.002	<0.002	<0.002
11(10m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.12	3.86	<0.05	<0.05	0.274	0.256	0.003	<0.002	<0.002	0.003
11(14m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.06	4.00	<0.05	<0.05	0.265	0.267	<0.002	<0.002	0.011	0.002

4.0 RESULTS AND DISCUSSION

4.1 Water

4.1.1 **May 26-27, 1988.** Water quality results can be found in Table 2, and lake profile data in Table 3.

The temperature-conductivity profiles performed during the May survey showed an increase of conductivity with depth at all stations, with the greatest change for the eastern stations. Surface conductivity varied from 176.1 to 184.6 µmhos/cm, while bottom conductivity readings were between 194.8 and 229.2 µmhos/cm. The thermocline was easier to define in the eastern part of the lake. The western profile was performed a day later and strong winds increased the mixing of the epilimnion with the metalimnion. pH was in a neutral range of 7.1 to 7.7. The surface pH was always greater than at depth.

Cadmium levels were high at several stations. Total cadmium at one metre depth was 0.7 µg/L at Station 5; 1.4 µg/L at Station 6; 0.7 µg/L at Station 10; and 1.5 µg/L at Station 11. The sample at Station 9, 10 metres deep, was 2.8 µg/L. These are above the Canadian Council of Resources and Environment Ministers guidelines (CCREM, 1987) for the protection of aquatic life (0.2 µg/L, hardness <60 mg/L; or 0.8 µg/L, hardness 60-120 mg/L). All dissolved cadmium values were near or below the detection limit of 0.1 µg/L.

Total copper values were all above the detection limit while several dissolved samples were contaminated. The graphite furnace results were used since the analysis offered lower detection limits and greater precision. Generally total copper level deceased with depth; the highest values were found in the one metre sample at most stations. Significant copper concentrations were found at Station 4 (6.9 µg/L); Station 5 (9.4 µg/L); and Station 11 (8.1 µg/L). All copper samples in Goosly Lake were above the CCREM guideline for protection of aquatic life (2 µg/L, hardness <120 mg/L).

If possible, follow name and unit conventions (eg) Ag, Al, etc. and mg/L

(for following pages also)

TABLE 2:

WATER QUALITY - GOOSLY LAKE
May 26-27, 1988

Station (depth)	TOTICP AG MG/L	DISICP AG MG/L	TOTICP AL MG/L	DISICP AL MG/L	TOTICP AS MG/L	DISICP AS MG/L	TOTICP BA MG/L	DISICP BA MG/L	TOTICP CA MG/L	DISICP CA MG/L	TOTICP CD MG/L	TOTGF CD MG/L	DISICP CD MG/L	DISGF CD MG/L	TOTICP CO MG/L	DISICP CO MG/L	TOTICP CR MG/L	DISICP CR MG/L
4(1m)	<0.01	<0.01	0.19	0.07	<0.05	<0.05	0.026	0.022	16.8	15.4	<0.005	0.0001	<0.005	<0.0001	0.005	<0.005	<0.005	<0.005
4(5m)	<0.01	<0.01	0.30	<0.05	<0.05	<0.05	0.027	0.026	17.7	18.6	<0.005	<0.0001	<0.005	<0.0001	0.009	<0.005	<0.005	<0.005
4(16m)	<0.01	<0.01	0.23	0.06	<0.05	<0.05	0.032	0.023	20.2	16.6	<0.005	<0.0001	<0.005	<0.0001	<.005	<0.005	<0.005	<0.005
5(1m)	<0.01	<0.01	0.19	0.10	<0.05	<0.05	0.026	0.023	17.6	16.4	<0.005	0.0007	<0.005	<0.0001	<.005	<0.005	<0.005	<0.005
5(7m)	<0.01	<0.01	0.22	0.06	<0.05	<0.05	0.027	0.023	18.0	16.0	<0.005	<0.0001	<0.005	<0.0001	0.008	<0.005	<0.005	<0.005
5(16m)	<0.01	<0.01	0.19	<0.05	<0.05	<0.05	0.030	0.027	20.0	19.0	<0.005	0.0007	<0.005	<0.0001	<.005	<0.005	<0.005	<0.005
6(1m)	<0.01	<0.01	0.15	0.06	<0.05	<0.05	0.026	0.023	17.5	16.1	<0.005	0.0014	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
6(5m)	<0.01	<0.01	0.18	0.08	<0.05	<0.05	0.027	0.023	18.7	16.8	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.012	<0.005
6(15m)	<0.01	<0.01	<0.05	0.06	<0.05	<0.05	0.028	0.026	19.6	18.7	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
7(1m)	<0.01	<0.01	0.20	0.06	<0.05	<0.05	0.026	0.023	17.6	16.5	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
7(5m)	<0.01	<0.01	0.17	<0.05	<0.05	<0.05	0.027	0.024	18.0	17.1	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
7(16m)	<0.01	<0.01	0.05	<0.05	<0.05	<0.05	0.031	0.028	20.5	19.6	<0.005	0.0003	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
8(1m)	<0.01	<0.01	0.17	0.08	<0.05	<0.05	0.027	0.024	18.4	16.6	<0.005	<0.0001	<0.005	<0.0001	0.006	<0.005	<0.005	<0.005
8(5m)	<0.01	<0.01	0.12	0.06	<0.05	<0.05	0.028	0.024	20.2	17.1	<0.005	0.0003	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
8(13m)	<0.01	<0.01	0.20	0.06	<0.05	<0.05	0.030	0.026	19.8	18.4	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
9(1m)	<0.01	<0.01	0.22	0.05	<0.05	<0.05	0.027	0.024	18.1	16.9	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
9(10m)	<0.01	<0.01	0.21	0.07	<0.05	<0.05	0.027	0.024	18.1	17.0	<0.005	0.0028	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
9(15m)	<0.01	<0.01	0.22	0.05	<0.05	<0.05	0.030	0.025	19.7	17.9	<0.005	<0.0001	<0.005	<0.0001	0.009	<0.005	0.005	<0.005
10(1m)	<0.01	<0.01	0.21	0.09	<0.05	<0.05	0.027	0.024	18.2	16.7	<0.005	0.0007	<0.005	<0.0001	0.005	<0.005	<0.005	<0.005
10(10m)	<0.01	<0.01	0.18	<0.05	<0.05	<0.05	0.027	0.024	18.6	16.8	<0.005	<0.0001	<0.005	<0.0001	0.007	<0.005	<0.005	<0.005
10(13m)	<0.01	<0.01	0.42	0.07	0.08	<0.05	0.032	0.027	18.7	17.4	<0.005	<0.0001	<0.005	<0.0001	0.013	<0.005	<0.005	<0.005
11(1m)	<0.01	<0.01	0.21	0.05	<0.05	<0.05	0.027	0.024	18.0	17.1	<0.005	0.0015	<0.005	<0.0001	0.006	<0.005	<0.005	<0.005
11(10m)	<0.01	<0.01	0.16	<0.05	<0.05	<0.05	0.027	0.024	18.2	17.1	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
11(14m)	<0.01	<0.01	0.10	0.06	<0.05	<0.05	0.026	0.026	18.2	18.3	<0.005	<0.0001	<0.005	0.0002	<0.005	<0.005	<0.005	<0.005

In addition, on this table are, for example NH_3, NO_2, etc.

TABLE 2 (Cont.):

WATER QUALITY - GOOSLY LAKE
May 26-27, 1988

Station (Depth)	ALK MG/L	DISICP HC MG/L	DISICP HT MG/L	TURB FTU	TR MG/L	NFR MG/L	NH3 MG/L	NO2 MG/L	NO2,3 MG/L	TIC MG/L	DIC MG/L	TOC MG/L	DOC MG/L	TC REL.U.	SO4 MG/L
4(1m)	35.0	53.9	54.7	2.0	127	7	0.043	<0.005	0.042	5	5	16	16	60	29
4(5m)	42.0	65.6	66.6	2.0	131	<5	0.012	<0.005	0.062	6	5	16	16	60	32
4(16m)	40.0	58.4	59.3	2.8	150	<5	<0.005	<0.005	0.127	7	7	16	14	50	38
5(1m)	35.5	57.7	58.8	1.8	127	6	0.027	<0.005	0.030	6	5	16	16	60	32
5(7m)	35.5	56.4	57.3	1.8	132	6	0.018	<0.005	0.073	5	5	17	16	60	33
5(16m)	39.0	66.8	67.8	2.5	143	<5	<0.005	<0.005	0.117	7	7	16	15	50	36
6(1m)	35.5	56.4	57.2	1.8	130	<5	0.031	<0.005	0.041	5	5	17	17	60	30
6(5m)	35.5	59.3	60.3	1.8	133	8	0.012	<0.005	0.062	5	6	17	16	60	32
6(15m)	38.5	66.1	67.2	2.3	151	<5	<0.005	<0.005	0.109	6	7	16	14	50	36
7(1m)	35.0	57.9	58.7	1.8	132	7	0.031	<0.005	0.048	5	5	16	16	60	31
7(5m)	35.0	60.1	61.0	1.8	137	<5	0.012	<0.005	0.066	5	5	17	16	60	32
7(16m)	39.5	69.4	70.4	2.3	128	7	<0.005	<0.005	0.135	6	7	16	15	50	33
8(1m)	35.0	58.5	59.5	1.5	129	<5	0.026	<0.005	0.053	5	5	16	15	60	31
8(5m)	35.5	60.4	61.2	1.8	135	<5	0.010	<0.005	0.071	6	5	16	16	60	33
8(13m)	37.0	65.2	66.2	2.8	137	<5	<0.005	<0.005	0.099	6	6	15	15	60	36
9(1m)	35.0	59.8	60.6	1.5	131	<5	0.016	<0.005	0.051	5	5	17	16	60	31
9(10m)	35.0	60.0	61.0	1.3	135	<5	0.015	<0.005	0.061	5	5	16	16	60	32
9(15m)	35.0	63.0	63.9	1.8	123	<5	<0.005	<0.005	0.085	6	6	16	16	60	34
10(1m)	35.5	59.1	60.1	1.3	118	<5	0.019	<0.005	0.057	5	5	17	16	50	32
10(10m)	35.5	59.6	60.5	1.8	114	<5	0.024	<0.005	0.068	5	5	16	16	60	32
10(13m)	35.5	61.7	62.8	5.3	135	<5	<0.005	<0.005	0.089	5	5	16	16	60	33
11(1m)	35.0	60.4	61.3	1.8	117	6	0.020	<0.005	0.065	6	5	16	16	60	31
11(10m)	35.0	60.2	60.9	1.8	126	<5	0.018	<0.005	0.073	5	5	15	16	60	31
11(14m)	37.0	64.8	65.8	2.0	119	<5	<0.005	<0.005	0.117	6	6	15	16	60	35

TABLE 3: GOOSLY LAKE TEMPERATURE-CONDUCTIVITY PROFILES - May 26-27, 1988

Station 4	Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
	1	176.1	9.3	7.7
	2	176.4	9.0	7.7
	3	182.8	7.4	7.5
	4	188.0	6.9	7.6
	5	192.6	6.3	7.5
	6	194.9	6.1	7.5
	7	197.1	6.0	7.5
	11	209.7	5.1	7.4
	15	221.9	4.5	7.4
	17	229.2	4.1	7.3

Station 5	Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
	1	179.3	9.1	7.5
	2	179.3	9.0	7.5
	3	179.5	8.9	7.5
	4	179.5	8.8	7.5
	5	179.8	8.5	7.5
	6	185.8	7.2	7.4
	7	192.4	6.4	7.4
	8	193.5	6.2	7.4
	9	196.8	5.9	7.4
	10	199.6	5.8	7.3
	11	208.8	5.4	7.3
	15	216.8	4.7	7.3
	16	224.8	4.4	7.2

Station 6	Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
	1	180.1	8.8	7.4
	2	180.9	8.7	7.4
	3	183.3	8.1	7.4
	4	186.0	7.7	7.4
	5	189.3	6.8	7.4
	6	192.4	6.4	7.3
	7	194.8	6.2	7.3
	8	197.1	6.0	7.3
	11	207.7	5.4	7.3
	13	210.8	5.2	7.3
	15	215.9	4.8	7.2
	16	220.2	4.7	7.2

TABLE 3 (cont.):
GOOSLY LAKE TEMPERATURE-CONDUCTIVITY PROFILE - May 26-27, 1988

Station 7	Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
	1	180.9	8.7	7.4
	2	181.9	8.4	7.4
	3	182.8	8.1	7.4
	4	188.2	7.1	7.4
	5	191.5	6.6	7.4
	6	194.3	6.3	7.3
	7	195.1	6.2	7.3
	8	197.9	6.0	7.3
	9	201.0	5.8	7.3
	10	202.9	5.6	7.2
	11	206.0	5.5	7.2
	16	213.3	5.1	7.2
	17	221.1	4.6	7.2

Station 8	Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
	1	181.1	8.6	7.4
	2	182.5	8.0	7.1
	3	183.6	7.7	7.1
	4	189.3	6.9	7.2
	5	192.9	6.5	7.2
	6	193.5	6.4	7.2
	7	197.3	6.0	7.2
	8	199.3	5.9	7.1
	9	199.8	5.9	7.2
	10	202.6	5.7	7.1
	15	205.7	5.5	7.2
	16	209.1	5.3	7.1

Station 9	Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
	1	184.1	8.7	7.4
	2	183.8	8.7	7.4
	3	183.3	8.7	7.5
	4	183.5	8.6	7.6
	5	183.3	8.6	7.6
	6	183.5	8.5	7.6
	7	183.0	8.5	7.6
	8	183.3	8.4	7.6
	9	184.4	8.2	7.6
	10	184.4	8.2	7.6
	11	184.4	8.2	7.6
	12	184.9	8.1	7.6
	13	186.0	7.9	7.5
	14	188.2	7.6	7.5
	15	191.2	7.2	7.5
	16	200.7	6.0	7.3

TABLE 3 (cont.):
GOOSLY LAKE TEMPERATURE-CONDUCTIVITY PROFILE - May 26-27, 1988

Station 10	Depth (m)	Conductivity (μmhos/cm)	Temperature (°C)	pH
	1	184.6	8.9	7.4
	2	184.1	8.7	7.4
	3	182.7	8.7	7.3
	4	182.5	8.7	7.3
	5	182.5	8.7	7.3
	6	182.2	8.7	7.4
	7	183.0	8.5	7.4
	8	182.7	8.5	7.4
	9	182.7	8.5	7.4
	10	183.0	8.5	7.4
	11	183.0	8.5	7.4
	13	184.9	8.2	7.4
	15	186.5	7.9	7.3
	16	189.3	7.5	7.4
	17	194.8	6.7	7.3

Station 11	Depth (m)	Conductivity (μmhos/cm)	Temperature (°C)	pH
	1	180.6	9.0	-
	2	181.1	8.7	-
	3	180.9	8.7	-
	4	180.9	8.7	-
	5	181.4	8.6	-
	6	181.4	8.6	-
	7	181.4	8.5	-
	8	181.7	8.5	-
	11	184.9	8.0	-
	15	210.8	5.2	-
	16	223.0	4.6	-

The mercury, lead, and chromium samples were near or below the detection limit. Zinc, although detectable, was always below the 0.03 mg/L CCREM guideline. These metal values are not suspected to cause problems for aquatic life.

Most of the total organic carbon was dissolved, varying 14 to 17 mg/L. Sulphate levels were fairly consistent throughout the lake with levels of 29 to 38 mg/L. Colour was high at 50-60 relative units and turbidity was 1.3 to 5.3 FTU. Suspended solids were below or close to the detection limit of 5 mg/L while substantial dissolved solids were present in the water (114-151 mg/L).

4.1.2 <u>**June 22-23, 1988**</u>. Water quality results are presented in Table 4, and the lake profile data is in Table 5.

The thermocline was between 5 and 8 metres based on the lake stations temperature-conductivity profiles. Conductivity was lower at the surface, ranging from 170.5 to 178.8 µmhos/cm. The values at the bottom ranged from 184.5 to 193.5 µmhos/cm corresponding to a surface-bottom difference of 12 to 18 µmhos/cm. Most stations experienced a decrease in conductivity at the thermocline of 2 to 6 µmhos/cm from the surface. The pH values throughout the lake were between 7.0 and 7.8 pH units.

Total cadmium level was 0.9 µg/L at Station 6 (8 metres deep). This was above the CCREM guideline for the protection of aquatic life of 0.8 µg/L for hardness of 60 to 120 mg/L. Dissolved cadmium values were below or close to the detection limit of 0.1 µg/L. Some high dissolved cadmium values were due to contamination.

All lake samples had carbonate hardness ranging from 62.1 to 70.9 mg/L. Carbonous hardness was almost twice as high as in May 1988 while total hardness did not increase as much. This can be explained by the large amount of lime added for the control of acid mine drainage during the spring and summer. Alkalinity did not change from May to June. Alkalinity in May was similar to the hardness due to the water increasing in calcium content without benefiting from an increase in buffering capacity.

Total copper values were all above the detection limit while dissolved values were subject to several contaminations. The graphite furnace results were used since the analysis led to greater precision with lower detection values. Generally total copper levels decreased with depth; high values were found at the one metre deep sample at most stations. Significant copper concentrations were found at Station 4 (5.1 µg/L at 1 metre depth) and Station 11 (7.1 µg/L at 7 metres depth). All copper samples in Goosly Lake were above the CCREM guideline for protection of aquatic life (2 µg/L for water with hardness below 120 mg/L).

If poss. follow notes as per pp 18 and 21

TABLE 4 :

WATER QUALITY - GOOSLY LAKE
June 22-23, 1988

Station (Depth)	TOTICP AG MG/L	DISICP AG MG/L	TOTICP AL MG/L	DISICP AL MG/L	TOTICP AS MG/L	DISICP AS MG/L	TOTICP BA MG/L	DISICP BA MG/L	TOTICP CA MG/L	DISICP CA MG/L
4(1m)	<0.01	<0.01	0.09	<0.05	<0.05	<0.05	0.024	0.024	18.7	18.1
4(5m)	<0.01	<0.01	0.11	<0.05	<0.05	<0.05	0.025	0.025	19.2	18.4
4(16m)	<0.01	<0.01	0.17	<0.05	<0.05	<0.05	0.029	0.026	20.6	19.4
5(1m)	<0.01	<0.01	0.10	<0.05	<0.05	<0.05	0.024	0.024	18.4	17.9
5(9m)	<0.01	<0.01	0.12	<0.05	<0.05	<0.05	0.024	0.025	18.4	18.3
5(16m)	<0.01	<0.01	0.12	<0.05	<0.05	<0.05	0.025	0.025	19.1	18.8
6(1m)	<0.01	<0.01	0.09	<0.05	<0.05	<0.05	0.024	0.025	18.4	18.5
6(8m)	<0.01	<0.01	0.11	<0.05	<0.05	<0.05	0.024	0.024	18.3	18.3
6(14m)	<0.01	0.01	0.12	0.06	<0.05	<0.05	0.029	0.028	21.2	20.1
7(1m)	<0.01	<0.01	0.12	<0.05	<0.05	<0.05	0.026	0.024	20.0	18.1
7(7m)	<0.01	<0.01	0.08	<0.05	<0.05	<0.05	0.027	0.024	20.2	18.3
7(17m)	<0.01	<0.01	0.08	<0.05	<0.05	<0.05	0.026	0.025	19.1	18.7
8(1m)	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	0.025	0.024	19.3	18.2
8(7m)	<0.01	<0.01	0.09	<0.05	<0.05	<0.05	0.026	0.025	19.9	18.4
8(16m)	<0.01	<0.01	0.10	<0.05	<0.05	<0.05	0.028	0.027	20.5	20.1
9(1m)	<0.01	<0.01	0.05	<0.05	<0.05	<0.05	0.026	0.024	19.5	18.3
9(7m)	<0.01	<0.01	0.09	<0.05	<0.05	<0.05	0.027	0.024	20.3	18.2
9(14m)	<0.01	<0.01	0.12	0.07	<0.05	<0.05	0.032	0.027	23.3	20.0
10(1m)	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	0.027	0.024	20.7	18.3
10(7m)	<0.01	<0.01	0.10	<0.05	<0.05	<0.05	0.025	0.024	19.2	18.4
10(15m)	<0.01	<0.01	0.09	<0.05	<0.05	<0.05	0.034	0.028	23.0	20.4
11(1m)	<0.01	<0.01	0.06	<0.05	<0.05	<0.05	0.028	0.024	21.4	18.4
11(7m)	<0.01	<0.01	0.10	0.06	<0.05	<0.05	0.025	0.025	18.5	18.8
11(15m)	<0.01	<0.01	0.12	<0.05	<0.05	<0.05	0.029	0.027	21.0	19.9

Station (Depth)	TOTICP CD MG/L	TOTGF CD MG/L	DISICP CD MG/L	DISGF CD MG/L	TOTICP CO MG/L	DISICP CO MG/L	TOTICP CR MG/L	DISICP CR MG/L
4(1m)	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
4(5m)	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
4(16m)	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
5(1m)	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
5(9m)	<0.005	0.0004	<0.005	0.0002	<0.005	<0.005	<0.005	<0.005
5(16m)	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
6(1m)	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
6(8m)	<0.005	0.0009	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
6(14m)	<0.005	0.0003	<0.005	0.0001	<0.005	0.005	<0.005	0.007
7(1m)	<0.005	0.0006	<0.005	0.0002	<0.005	<0.005	<0.005	<0.005
7(7m)	<0.005	<0.0001	<0.005	0.0002	<0.005	<0.005	<0.005	<0.005
7(17m)	<0.005	<0.0001	<0.005	0.0003	<0.005	<0.005	<0.005	<0.005
8(1m)	<0.005	<0.0001	<0.005	0.0003	<0.005	<0.005	<0.005	<0.005
8(7m)	<0.005	<0.0001	<0.005	0.0004	<0.005	<0.005	<0.005	<0.005
8(16m)	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
9(1m)	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
9(7m)	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
9(14m)	<0.005	0.0004	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
10(1m)	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
10(7m)	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
10(15m)	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
11(1m)	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
11(7m)	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
11(15m)	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005

TABLE 4 (Cont.):

WATER QUALITY - GOOSLY LAKE
June 22-23, 1988

Station (Depth)	TOTICP CU MG/L	TOTGF CU MG/L	DISICP CU MG/L	DISGF CU MG/L	TOTICP FE MG/L	DISICP FE MG/L	TOTICP MG MG/L	DISICP MG MG/L	TOTICP MN MG/L	DISICP MN MG/L	TOTICP MO MG/L	DISICP MO MG/L	TOTICP NA MG/L	DISICP NA MG/L	TOTICP NI MG/L	DISICP NI MG/L
4(1m)	0.007	0.0051	<0.005	0.0049	0.167	0.091	4.3	4.3	0.013	<0.001	<0.01	<0.01	3.7	3.4	<0.02	<0.02
4(5m)	<0.005	0.0042	0.008	0.0038	0.218	0.093	4.5	4.5	0.020	<0.001	<0.01	<0.01	3.9	3.6	<0.02	<0.02
4(16m)	<0.005	0.0044	<0.005	0.0035	0.272	0.092	4.9	4.7	0.053	<0.001	<0.01	<0.01	4.2	3.7	<0.02	<0.02
5(1m)	<0.005	0.0045	<0.005	0.0043	0.168	0.085	4.3	4.2	0.013	<0.001	<0.01	<0.01	3.8	3.4	<0.02	<0.02
5(9m)	0.006	0.0048	<0.005	0.0039	0.197	0.093	4.3	4.4	0.016	<0.001	<0.01	<0.01	3.8	3.6	<0.02	<0.02
5(16m)	0.006	0.0046	<0.005	0.0041	0.242	0.111	4.4	4.4	0.028	<0.001	<0.01	<0.01	3.7	3.4	<0.02	<0.02
6(1m)	<0.005	0.0045	<0.005	0.0040	0.194	0.092	4.3	4.4	0.012	<0.001	<0.01	<0.01	3.7	3.5	<0.02	<0.02
6(8m)	0.006	0.0045	<0.005	0.0038	0.184	0.086	4.3	4.4	0.015	<0.001	<0.01	<0.01	3.7	3.4	<0.02	<0.02
6(14m)	<0.005	0.0037	0.009	0.0040	0.258	0.102	5.0	5.0	0.072	<0.001	<0.01	<0.01	4.3	3.9	<0.02	<0.02
7(1m)	0.006	0.0048	<0.005	0.0042	0.195	0.086	4.7	4.3	0.012	<0.001	<0.01	<0.01	4.0	3.5	<0.02	<0.02
7(7m)	<0.005	0.0048	<0.005	0.0041	0.200	0.089	4.7	4.4	0.015	<0.001	<0.01	<0.01	4.0	3.4	<0.02	<0.02
7(17m)	<0.005	0.0041	<0.005	0.0042	0.207	0.094	4.5	4.6	0.023	<0.001	<0.01	<0.01	3.8	3.6	<0.02	<0.02
8(1m)	<0.005	0.0044	<0.005	0.0041	0.153	0.086	4.4	4.3	0.010	<0.001	<0.01	<0.01	3.7	3.4	<0.02	<0.02
8(7m)	<0.005	0.0044	<0.005	0.0038	0.187	0.091	4.6	4.5	0.014	<0.001	<0.01	<0.01	3.9	3.5	<0.02	<0.02
8(16m)	<0.005	0.0035	<0.005	0.0036	0.247	0.098	4.8	4.9	0.075	<0.001	<0.01	<0.01	4.1	3.8	<0.02	<0.02
9(1m)	0.006	0.0048	<0.005	0.0043	0.174	0.094	4.5	4.4	0.013	<0.001	<0.01	<0.01	3.8	3.4	<0.02	<0.02
9(7m)	<0.005	0.0049	<0.005	0.0040	0.209	0.087	4.8	4.4	0.019	<0.001	<0.01	<0.01	4.1	3.4	<0.02	<0.02
9(14m)	<0.005	0.0039	0.006	0.0035	0.295	0.101	5.5	4.9	0.068	<0.001	<0.01	<0.01	4.7	3.8	<0.02	<0.02
10(1m)	<0.005	0.0047	<0.005	0.0043	0.160	0.088	4.8	4.4	0.013	<0.001	<0.01	<0.01	4.1	3.5	<0.02	<0.02
10(7m)	<0.005	0.0037	<0.005	0.0031	0.231	0.086	4.4	4.4	0.016	<0.001	<0.01	<0.01	3.8	3.6	<0.02	<0.02
10(15m)	<0.005	0.0032	<0.005	0.0019	0.322	0.102	5.4	4.9	0.142	<0.001	<0.01	<0.01	4.6	3.9	<0.02	<0.02
11(1m)	<0.005	0.0041	<0.005	0.0038	0.190	0.091	4.9	4.3	0.014	<0.001	<0.01	<0.01	4.2	3.5	<0.02	<0.02
11(7m)	0.008	0.0071	0.008	0.0030	0.203	0.096	4.4	4.4	0.019	<0.001	<0.01	<0.01	3.7	3.6	<0.02	<0.02
11(15m)	<0.005	0.0040	0.007	0.0023	0.269	0.099	4.9	4.8	0.054	<0.001	<0.01	<0.01	4.1	3.8	<0.02	<0.02

TABLE 4 (Cont.):

WATER QUALITY - GOOSLY LAKE
June 22-23, 1988

Station (Depth)	TOTICP P MG/L	DISICP P MG/L	TOTICP PB MG/L	TOTGF PB MG/L	DISICP PB MG/L	DISGF PB MG/L	DISICP SB MG/L	TOTICP SB MG/L	TOTICP SI MG/L	DISICP SI MG/L	TOTICP SN MG/L	DISICP SN MG/L	TOTICP SR MG/L	DISICP SR MG/L	TOTICP TI MG/L	DISICP TI MG/L	TOTICP ZN MG/L	DISICP ZN MG/L
4(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	0.0005	<0.05	<0.05	4.14	3.88	<0.05	<0.05	0.272	0.283	0.003	<0.002	0.004	0.006
4(5m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.34	4.03	<0.05	<0.05	0.259	0.266	0.003	0.002	<0.002	<0.002
4(16m)	<0.1	0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.58	4.19	<0.05	<0.05	0.274	0.274	0.004	<0.002	<0.002	<0.002
5(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.05	3.83	<0.05	<0.05	0.266	0.279	<0.002	<0.002	0.003	<0.002
5(9m)	<0.1	<0.1	<0.05	<0.0005	<0.05	0.0007	<0.05	<0.05	4.10	4.02	<0.05	<0.05	0.249	0.270	0.003	<0.002	<0.002	<0.002
5(16m)	<0.1	<0.1	<0.05	<0.0005	<0.05	0.0006	<0.05	<0.05	4.27	4.07	<0.05	<0.05	0.274	0.290	0.003	<0.002	<0.002	<0.002
6(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	0.0007	0.06	<0.05	3.95	3.89	<0.05	<0.05	0.266	0.287	<0.002	<0.002	<0.002	<0.002
6(8m)	<0.1	<0.1	<0.05	<0.0005	<0.05	0.0008	<0.05	<0.05	4.10	3.99	<0.05	<0.05	0.250	0.272	0.002	<0.002	<0.002	<0.002
6(14m)	<0.1	<0.1	<0.05	<0.0005	<0.05	0.0011	0.06	<0.05	4.64	4.28	<0.05	<0.05	0.276	0.280	0.003	0.003	<0.002	<0.002
7(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	0.0007	<0.05	<0.05	4.32	3.83	<0.05	<0.05	0.293	0.283	0.003	<0.002	0.006	<0.002
7(7m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.47	3.99	<0.05	<0.05	0.279	0.272	0.003	<0.002	<0.002	<0.002
7(17m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.26	4.06	<0.05	<0.05	0.256	0.270	0.003	<0.002	<0.002	<0.002
8(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.17	3.84	<0.05	<0.05	0.279	0.284	<0.002	<0.002	<0.002	<0.002
8(7m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.40	4.01	<0.05	<0.05	0.275	0.272	0.002	<0.002	<0.002	<0.002
8(16m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.48	4.31	<0.05	<0.05	0.267	0.282	0.002	<0.002	<0.002	<0.002
9(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.26	3.90	<0.05	<0.05	0.283	0.287	0.003	<0.002	<0.002	<0.002
9(7m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.49	4.02	<0.05	<0.05	0.279	0.270	0.003	<0.002	<0.002	<0.002
9(14m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	5.10	4.26	<0.05	<0.05	0.310	0.279	0.004	<0.002	<0.002	<0.002
10(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.37	3.89	<0.05	<0.05	0.306	0.285	<0.002	<0.002	<0.002	<0.002
10(7m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.33	4.01	<0.05	<0.05	0.262	0.271	0.003	<0.002	0.030	0.003
10(14m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	5.09	4.33	<0.05	<0.05	0.303	0.281	0.003	<0.002	<0.002	<0.002
11(1m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.68	3.89	<0.05	<0.05	0.316	0.285	0.003	<0.002	0.005	0.004
11(7m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.20	4.09	<0.05	<0.05	0.251	0.269	0.003	<0.002	<0.002	<0.002
11(15m)	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	4.65	4.25	<0.05	<0.05	0.276	0.279	0.003	<0.002	0.008	<0.002

TABLE 4 (Cont.):

WATER QUALITY - GOOSLY LAKE
June 22-23, 1988

Station (Depth)	ALK MG/L	DISICP HC MG/L	DISICP HT MG/L	COND UMHO/C	PH REL.U.	TURB FTU	TR MG/L	NFR MG/L	TIC MG/L	TOC MG/L	DIC MG/L	DOC MG/L	SO4 MG/L
4(1m)	35.0	62.7	63.2	138	7.8	0.5	124	<5	4	17	4	15	28
4(5m)	35.0	64.2	64.8	135	7.8	0.9	114	<5	5	16	4	13	31
4(16m)	36.0	67.7	68.1	148	7.9	1.8	127	<5	6	15	5	12	33
5(1m)	35.5	62.1	62.7	138	7.9	0.6	122	<5	4	17	4	15	29
5(9m)	36.5	63.9	64.4	140	8.0	0.7	120	<5	4	17	5	12	31
5(16m)	37.5	65.1	65.8	140	8.0	0.8	129	<5	5	16	5	13	31
6(1m)	35.0	64.2	64.8	135	7.9	0.5	124	<5	4	17	4	14	30
6(8m)	34.5	63.9	64.1	138	7.9	0.7	126	<5	5	16	4	12	30
6(14m)	37.0	70.6	71.4	150	7.9	0.9	132	<5	6	14	6	12	30
7(1m)	35.0	63.2	63.6	135	7.9	0.5	125	<5	5	16	4	14	29
7(7m)	35.0	63.9	64.4	138	7.9	0.6	115	<5	5	16	4	12	29
7(17m)	35.0	65.5	66.1	140	7.9	1.0	122	<5	5	16	5	12	31
8(1m)	35.0	63.3	63.8	138	7.9	0.6	118	<5	4	16	4	13	29
8(7m)	35.0	64.5	65.1	138	7.9	0.7	115	<5	5	15	4	13	30
8(16m)	36.0	70.5	70.9	148	7.9	1.8	128	<5	6	14	6	11	34
9(1m)	35.0	63.6	64.2	135	7.9	0.6	122	<5	5	18	--	--	30
9(7m)	35.0	63.6	64.2	138	7.9	0.8	123	<5	5	17	--	--	31
9(14m)	37.0	70.0	70.9	148	7.9	0.9	130	<5	5	15	4	12	33
10(1m)	35.0	63.8	64.2	135	7.9	0.5	122	<5	4	16	4	15	30
10(7m)	35.0	64.2	64.7	138	8.0	0.6	114	<5	4	16	4	13	32
10(15m)	37.0	70.9	71.5	150	7.9	2.3	130	6	6	13	4	12	35
11(1m)	35.0	63.8	64.4	138	7.9	0.6	116	<5	4	16	4	13	30
11(17m)	35.0	65.2	66.0	138	8.0	0.7	118	<5	5	15	4	13	30
11(15m)	37.0	69.3	70.0	148	7.9	0.8	137	<5	6	14	--	--	33

TABLE 5: GOOSLY LAKE TEMPERATURE-CONDUCTIVITY PROFILES - June 22-23, 1988

Station 4	Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
	1	175.8	13.4	7.0
	2	173.0	13.3	7.3
	3	172.5	13.2	7.4
	4	172.5	13.0	7.6
	5	172.0	12.9	7.6
	6	171.8	11.2	7.5
	7	173.3	9.2	7.3
	8	173.0	8.6	7.2
	9	174.8	8.0	7.2
	10	176.3	7.7	7.1
	14	190.3	5.9	7.1
	16	191.0	5.7	7.0
	17	191.3	5.6	7.0

Station 5	Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
	1	172.8	13.3	7.1
	2	172.5	12.9	7.4
	3	172.0	11.7	7.4
	4	171.5	11.5	7.4
	5	171.5	11.4	7.4
	6	171.8	11.2	7.4
	7	177.3	10.6	7.4
	8	172.5	9.2	7.3
	9	174.0	8.1	7.3
	10	177.8	7.5	7.2
	11	183.3	6.7	7.0
	12	185.8	6.4	7.2
	14	188.5	6.0	7.2
	16	189.8	5.8	7.1
	17	190.8	5.6	7.0

Station 6	Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
	1	176.0	12.6	-
	2	175.8	12.5	-
	3	174.5	12.5	-
	4	174.0	12.5	-
	5	174.0	11.5	-
	6	175.8	9.4	-
	7	175.0	8.6	-
	8	176.3	8.0	-
	9	180.0	7.4	-
	10	180.8	7.1	-
	12	192.0	6.7	-
	14	186.5	6.4	-
	15	188.8	6.1	-

TABLE 5 (cont.):
GOOSLY LAKE TEMPERATURE-CONDUCTIVITY PROFILES - June 22-23, 1988

Station 7	Depth (m)	Conductivity (μmhos/cm)	Temperature (°C)	pH
	1	177.0	13.4	7.7
	2	175.8	12.8	7.7
	3	175.3	12.7	7.7
	4	175.0	12.3	7.7
	5	174.5	11.1	7.5
	6	175.8	9.4	7.4
	7	176.0	8.5	7.4
	8	176.5	8.2	7.3
	9	178.3	7.9	7.3
	10	179.8	7.7	7.3
	12	182.8	7.1	7.3
	14	188.5	6.3	7.2
	15	189.8	6.1	7.2
	16	191.0	5.9	7.1

Station 8	Depth (m)	Conductivity (μmhos/cm)	Temperature (°C)	pH
	1	178.8	13.4	7.8
	2	175.5	12.7	7.8
	3	175.0	12.6	7.7
	4	174.3	122.4	7.7
	5	172.8	11.2	7.5
	6	174.3	9.7	7.3
	7	174.8	8.9	7.3
	8	175.8	8.4	7.3
	9	176.3	8.0	7.3
	10	177.5	7.8	7.3
	12	179.8	7.4	7.2
	14	184.3	6.8	7.2
	15	187.3	6.4	7.1
	16	188.8	6.1	7.1
	17	191.5	5.7	7.0

Station 9	Depth (m)	Conductivity (μmhos/cm)	Temperature (°C)	pH
	1	172.7	13.2	7.7
	2	172.3	12.9	7.7
	3	171.8	12.6	7.7
	4	172.5	10.9	7.6
	5	173.0	9.3	7.5
	6	173.3	8.8	7.4
	7	174.0	8.2	7.3
	8	175.8	7.8	7.3
	9	176.0	7.7	7.3
	10	177.5	7.6	7.3
	12	181.0	6.9	7.3
	14	188.0	6.0	7.2
	15	189.5	5.8	7.2

TABLE 5 (cont.):
GOOSLY LAKE TEMPERATURE-CONDUCTIVITY PROFILES - June 22-23, 1988

Station 10	Depth (m)	Conductivity (μmhos/cm)	Temperature (°C)	pH
	1	176.3	12.5	7.7
	2	175.3	12.4	7.7
	3	175.0	12.1	7.7
	4	174.5	11.7	7.6
	5	175.3	11.0	7.5
	6	176.3	10.2	7.4
	7	176.5	8.1	7.3
	8	179.5	7.6	7.3
	9	183.3	7.1	7.2
	10	187.5	6.4	7.1
	14	193.5	5.7	7.1
	16	193.5	5.6	7.1

Station 11	Depth (m)	Conductivity (μmhos/cm)	Temperature (°C)	pH
	1	170.5	13.0	7.6
	2	169.3	12.8	7.7
	3	169.0	12.5	7.7
	4	169.5	12.0	7.7
	5	170.3	10.0	7.5
	6	171.8	8.5	7.4
	7	172.8	8.2	7.4
	8	173.3	8.0	7.3
	9	173.8	7.9	7.3
	10	174.3	7.7	7.3
	12	177.8	7.3	7.3
	14	182.0	6.7	7.2
	15	184.5	6.4	7.2

The creek sample results showed an increase of copper at Station 3 downstream of the mine discharge (Table 6). The copper level never returned to the background level after leaving Goosly Lake, both on the total and dissolved basis. Substantial precipitation of dissolved iron and manganese could be observed after the water leaves the lake. The cadmium values were lower than the lake results. It seems that the cadmium concentrations may reside longer in the lake than the creek. The hardness and sulphate were clearly influenced by the mine discharge. The water residence in the lake did not reduce these parameters to background levels. Total organic carbon was not substantially influenced by the mine discharge or the lake residence time.

Same notes as per Tables 2+4

TABLE 6 :

WATER QUALITY - BUCK CREEK
June 22-23, 1988

Station		TOTICP AG MG/L	DISICP AG MG/L	TOTICP AL MG/L	DISICP AL MG/L	TOTICP AS MG/L	DISICP AS MG/L	TOTICP BA MG/L	DISICP BA MG/L	TOTICP CA MG/L	DISICP CA MG/L	TOTICP CD MG/L	TOTGF CD MG/L	DISICP CD MG/L	DISGF CD MG/L	TOTICP CO MG/L	DISICP CO MG/L	TOTICP CR MG/L	DISICP CR MG/L
	Repl. 1	<0.01	<0.01	0.18	<0.05	<0.05	<0.05	0.026	0.022	12.9	11.8	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	<0.006	<0.005
1	Repl. 2	<0.01	<0.01	0.20	<0.05	<0.05	<0.05	0.023	0.022	11.6	11.6	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
	Repl. 3	<0.01	<0.01	0.17	<0.05	<0.05	<0.05	0.024	0.022	12.0	11.4	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
	Average	--	--	0.18	--	--	--	0.024	0.022	12.2	11.6	--	0.0002	--	--	--	--	--	--
	S.D.	--	--	0.02	--	--	--	0.002	0.000	0.7	0.2	--	0.0000	--	--	--	--	--	--
2	Repl. 1	<0.01	<0.01	0.62	0.07	<0.05	0.06	0.056	0.049	123.0	112.0	<0.005	0.0028	<0.005	0.0008	<0.005	<0.005	<0.005	<0.005
	Repl. 1	<0.01	<0.01	0.13	<0.05	<0.05	<0.05	0.029	0.028	25.0	24.1	<0.005	0.0002	<0.005	0.0001	<0.005	<0.005	<0.005	<0.005
3	Repl. 2	<0.01	<0.01	0.17	0.05	<0.05	0.05	0.027	0.028	23.5	24.1	<0.005	0.0002	<0.005	0.0001	<0.005	<0.005	<0.005	<0.005
	Repl. 3	<0.01	<0.01	0.17	0.05	<0.05	<0.05	0.028	0.027	24.3	24.1	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
	Average	--	--	0.16	0.05	--	--	0.028	0.028	24.3	24.1	--	0.0002	--	0.0001	--	--	--	--
	S.D.	--	--	0.02	0.00	--	--	0.001	0.001	0.8	0.0	--	0.0000	--	0.0000	--	--	--	--
	Repl. 1	<0.01	<0.01	0.09	<0.05	<0.05	<0.05	0.024	0.025	18.1	18.2	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
13	Repl. 2	<0.01	<0.01	0.08	<0.05	<0.05	<0.05	0.025	0.024	18.6	18.2	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
	Repl. 3	<0.01	<0.01	<.05	<0.05	<0.05	<0.05	0.025	0.024	18.4	18.2	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
	Average	--	--	0.09	--	--	--	0.025	0.024	18.4	18.2	--	0.0001	--	--	--	--	--	--
	S.D.	--	--	0.01	--	--	--	0.001	0.001	0.3	0.0	--	0.0000	--	--	--	--	--	--

TABLE 6 (Cont.):

WATER QUALITY - BUCK CREEK
June 22-23, 1988

Station		TOTICP CU MG/L	TOTGF CU MG/L	DISICP CU MG/L	DISGF CU MG/L	TOTICP FE MG/L	DISICP FE MG/L	TOTICP MG MG/L	DISICP MG MG/L	TOTICP MN MG/L	DISICP MN MG/L	TOTICP MO MG/L	DISICP MO MG/L	TOTICP NA MG/L	DISICP NA MG/L	TOTICP NI MG/L	DISICP NI MG/L
1	Repl. 1	<0.005	0.0010	<0.005	<0.005	0.449	0.265	3.4	3.2	0.028	0.019	<0.01	<0.01	2.7	2.3	<0.02	<0.02
	Repl. 2	0.005	0.0014	<0.005	<0.005	0.409	0.257	3.1	3.1	0.025	0.018	<0.01	<0.01	2.6	2.3	<0.02	<0.02
	Repl. 3	<0.005	0.0017	<0.005	<0.005	0.425	0.255	3.2	3.1	0.026	0.018	<0.01	<0.01	2.5	2.3	<0.02	<0.02
	Average	--	0.0014	--	--	0.428	0.259	3.2	3.1	0.026	0.018	--	--	2.6	2.3	--	--
	S.D.	--	0.0004	--	--	0.020	0.005	0.2	0.1	0.002	0.001	--	--	0.1	0.0	--	--
2	Repl. 1	0.038	--	0.028	--	0.449	0.020	17.6	16.6	0.223	0.189	<0.01	<0.01	9.3	8.1	<0.02	<0.02
3	Repl. 1	<0.005	0.0042	<0.005	0.0033	0.449	0.292	5.1	5.0	0.057	0.048	<0.01	<0.01	3.6	3.3	<0.02	<0.02
	Repl. 2	<0.005	0.0045	<0.005	0.0031	0.441	0.297	4.7	5.0	0.053	0.048	<0.01	<0.01	3.3	3.3	<0.02	<0.02
	Repl. 3	0.005	0.0043	<0.005	0.0031	0.456	0.298	4.9	5.0	0.055	0.049	<0.01	<0.01	3.5	3.2	<0.02	<0.02
	Average	--	0.0043	--	0.0032	0.449	0.296	4.9	5.0	0.055	0.048	--	--	3.5	3.3	--	--
	S.D.	--	0.0002	--	0.0001	0.008	0.003	0.2	0.0	0.002	0.001	--	--	0.2	0.1	--	--
13	Repl. 1	0.006	0.0041	<0.005	0.0024	0.177	0.095	4.3	4.3	0.021	0.002	<0.01	<0.01	3.7	3.5	<0.02	<0.02
	Repl. 2	<0.005	0.0037	<0.005	0.0025	0.204	0.094	4.4	4.3	0.024	0.004	<0.01	<0.01	3.8	3.5	<0.02	<0.02
	Repl. 3	0.005	0.0036	<0.005	0.0035	0.189	0.096	4.3	4.4	0.021	0.003	<0.01	<0.01	3.8	3.6	<0.02	<0.02
	Average	0.006	0.0038	--	0.0028	0.190	0.095	4.3	4.3	0.022	0.003	--	--	3.8	3.5	--	--
	S.D.	0.001	0.0003	--	0.0006	0.014	0.001	0.1	0.1	0.002	0.001	--	--	0.1	0.1	--	--

TABLE 6 (Cont.):

WATER QUALITY - BUCK CREEK
June 22-23, 1988

Station		TOTICP P MG/L	DISICP P MG/L	TOTICP PB MG/L	TOTGF PB MG/L	DISICP PB MG/L	DISGF PB MG/L	DISICP SB MG/L	TOTICP SB MG/L	TOTICP SI MG/L	DISICP SI MG/L	TOTICP SN MG/L	DISICP SN MG/L	TOTICP SR MG/L	DISICP SR MG/L	TOTICP TI MG/L	DISICP TI MG/L	TOTICP ZN MG/L	DISICP ZN MG/L
	Repl. 1	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	5.80	5.13	<0.05	<0.05	0.120	0.113	0.006	<0.002	<0.002	<0.002
1	Repl. 2	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	5.23	5.12	<0.05	<0.05	0.105	0.111	0.007	0.002	<0.002	<0.002
	Repl. 3	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	5.49	5.03	<0.05	<0.05	0.109	0.110	0.005	<0.002	<0.002	<0.002
	Average	--	--	--	--	--	--	--	--	5.51	5.09	--	--	0.111	0.111	0.006	--	--	--
	S.D.	--	--	--	--	--	--	--	--	0.29	0.06	--	--	0.008	0.002	0.001	--	--	--
2	Repl. 1	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	0.07	<0.05	5.58	4.51	<0.05	<0.05	4.140	4.010	0.010	0.002	0.051	0.040
	Repl. 1	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	5.52	5.22	<0.05	<0.05	0.515	0.532	0.004	<0.002	<0.002	<0.002
3	Repl. 2	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	5.29	5.27	<0.05	<0.05	0.477	0.534	0.005	<0.002	<0.002	<0.002
	Repl. 3	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	5.46	5.29	<0.05	<0.05	0.500	0.534	0.005	<0.002	<0.002	<0.002
	Average	--	--	--	--	--	--	--	--	5.42	5.26	--	--	0.497	0.533	0.005	--	--	--
	S.D.	--	--	--	--	--	--	--	--	0.12	0.04	--	--	0.019	0.001	0.001	--	--	--
	Repl. 1	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	3.86	3.67	<0.05	<0.05	0.255	0.272	0.003	<0.002	<0.002	<0.002
13	Repl. 2	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	3.97	3.67	<0.05	<0.05	0.262	0.271	0.003	<0.002	<0.002	<0.002
	Repl. 3	<0.1	<0.1	<0.05	<0.0005	<0.05	<0.0005	<0.05	<0.05	3.89	3.68	<0.05	<0.05	0.259	0.274	0.003	<0.002	<0.002	<0.002
	Average	--	--	--	--	--	--	--	--	3.91	3.67	--	--	0.259	0.272	0.003	--	--	--
	S.D.	--	--	--	--	--	--	--	--	0.06	0.01	--	--	0.004	0.002	0.000	--	--	--

TABLE 6 (Cont.):

WATER QUALITY - BUCK CREEK
June 22-23, 1988

Station		ALK MG/L	DISICP HC MG/L	DISICP HT MG/L	COND UMHO/C	PH REL.U.	TURB FTU	TR MG/L	NFR MG/L	TIC MG/L	TOC MG/L	DIC MG/L	DOC MG/L	SO4 MG/L
	Repl. 1	39.5	42.5	43.4	83	7.9	0.6	88	<5	6	17	5	14	6
1	Repl. 2	40.0	41.9	42.8	83	8.0	0.6	94	<5	6	17	5	15	4
	Repl. 3	40.0	41.2	41.9	83	7.9	0.7	99	<5	6	17	5	14	4
	Average	39.8	41.9	42.7	83	7.9	0.6	94	--	6	17	5	14	5
	S.D.	0.3	0.7	0.8	0	0.1	0.1	6	--	0	0	0	1	1
2	Repl. 1	61.0	349	355	680	8.1	5.8	562	<5	10	10	10	7	250
	Repl. 1	41.5	80.7	82.1	160	8.0	0.6	142	<5	6	16	6	15	37
3	Repl. 2	42.0	80.8	82.3	160	8.0	0.6	147	<5	6	15	6	12	37
	Repl. 3	42.0	80.7	82.2	160	8.0	0.6	142	<5	7	14	6	13	37
	Average	41.8	80.7	82.2	160	8.0	0.6	144	--	6	15	6	13	37
	S.D.	0.3	0.1	0.1	0	0.0	0.0	3	--	1	1	0	2	0
	Repl. 1	35.0	63.3	63.8	133	8.0	0.4	123	<5	4	16	--	--	29
13	Repl. 2	35.0	63.2	63.9	135	7.9	0.4	125	<5	4	16	--	--	28
	Repl. 3	35.0	63.3	63.9	133	8.0	0.3	115	<5	4	16	--	--	29
	Average	35.0	63.3	63.9	134	8.0	0.4	121	--	4	16	--	--	29
	S.D.	0.0	0.1	0.1	1	0.1	0.1	5	--	0	0	--	--	1

4.1.3 **June 30 - July 2, 1989.** The water quality results are given in Table 7, and lake profile data in Table 8.

The thermocline was between 5 and 6 metres depth. There was an increase in conductivity between the surface and the bottom, however measurements fluctuated near the thermocline. pH decreased from the surface (7.9) to the bottom (7.0).

Cadmium concentrations in the lake did not increase compared to the 1988 surveys. Although only the middle lake station was sampled (Station 12), all samples were below the detection limit. Total and dissolved copper levels were above the CCREM guidelines for the protection of aquatic life. Total organic carbon was high (21 to 23 mg/L) compared to the June 1988 survey (14 to 18 mg/L). Hardness was comparable to the June 1988 survey.

The Buck Creek upstream and downstream stations were all below the detection limit for total and dissolved cadmium. Copper had a different response as Station 3 and 13 had dissolved fraction concentrations almost identical to the discharge concentrations at Station 2. The dissolved level at the control station was five times less.

TABLE 8: GOOSLY LAKE TEMPERATURE-CONDUCTIVITY PROFILE - June 30, 1989

Station 12	Depth (m)	Conductivity (µmhos/cm)	Temperature (°C)	pH
	1	164.8	14.8	7.9
	2	165.8	14.6	7.7
	3	173.3	13.4	7.6
	4	163.8	12.5	7.5
	5	157.5	10.4	7.3
	6	161.3	8.8	7.2
	7	162.8	7.4	7.2
	8	163.0	6.8	7.2
	9	163.3	6.4	7.1
	10	164.3	6.1	7.0
	15	168.5	5.1	7.2
	16	169.5	5.1	7.0

Name and unit conventions, if poss. (all ↑ pages)

TABLE 7 :

WATER QUALITY - BUCK CREEK SYSTEM
June 30, 1989

Station		TOTICP AG MG/L	DISICP AG MG/L	TOTICP AL MG/L	DISICP AL MG/L	TOTICP AS MG/L	DISICP AS MG/L	TOTICP BA MG/L	DISICP BA MG/L	TOTICP CA MG/L	DISICP CA MG/L	TOTICP CD MG/L	TOTGF CD MG/L	DISICP CD MG/L	DISGF CD MG/L	TOTICP CO MG/L	DISICP CO MG/L	TOTICP CR MG/L	DISICP CR MG/L
	Repl. 1	<0.01	<0.01	0.06	<0.05	<0.05	<0.05	0.027	0.025	14.1	13.4	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.007	<0.005
1	Repl. 2	<0.01	<0.01	0.19	<0.05	<0.05	<0.05	0.032	0.025	13.3	13.5	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.007	<0.005
	Repl. 3	<0.01	<0.01	0.14	<0.05	<0.05	<0.05	0.026	0.025	13.0	13.6	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
	Average	--	--	0.13	--	--	--	0.028	0.025	13.5	13.5	--	--	--	--	--	--	0.007	--
	S.D.	--	--	0.07	--	--	--	0.003	0.000	0.6	0.1	--	--	--	--	--	--	0.000	--
	Repl. 1	<0.01	<0.01	1.89	0.15	<0.05	<0.05	0.072	0.060	164	173	<0.005	0.0015	<0.005	0.0013	0.010	<0.005	0.006	<0.005
2	Repl. 2	<0.01	<0.01	1.62	0.15	<0.05	<0.05	0.071	0.060	165	172	<0.005	0.0013	<0.005	0.0014	0.011	<0.005	<0.005	<0.005
	Repl. 3	<0.01	<0.01	1.93	0.15	<0.05	<0.05	0.072	0.059	165	171	<0.005	0.0015	<0.005	0.0014	0.013	<0.005	0.006	<0.005
	Average	--	--	1.81	0.15	--	--	0.072	0.060	165	172	--	0.0014	--	0.0014	0.011	--	0.006	--
	S.D.	--	--	0.17	0.00	--	--	0.001	0.001	0.6	1.0	--	0.0001	--	0.0001	0.002	--	0.000	--
	Repl. 1	<0.01	<0.01	0.18	<0.05	<0.05	<0.05	0.042	0.005	43.8	62.4	<0.005	<0.0001	<0.005	<0.0001	0.005	<0.005	<0.005	<0.005
3	Repl. 2	<0.01	<0.01	0.42	<0.05	<0.05	0.05	0.048	0.040	45.6	45.7	<0.005	<0.0001	<0.005	<0.0001	0.005	<0.005	0.005	<0.005
	Repl. 3	<0.01	<0.01	0.96	<0.05	<0.05	<0.05	0.054	0.039	44.2	44.6	<0.005	<0.0001	<0.005	<0.0001	0.007	<0.005	<0.005	<0.005
	Average	--	--	0.52	--	--	--	0.048	0.028	44.5	51.0	--	--	--	--	0.006	--	--	--
	S.D.	--	--	0.40	--	--	--	0.006	0.020	0.9	10.0	--	--	--	--	0.001	--	--	--
	(1 m)	<0.01	<0.01	0.10	<0.05	<0.05	<0.05	0.028	0.028	18.5	18.4	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
12	(3 m)	<0.01	<0.01	0.05	<0.05	<0.05	<0.05	0.025	0.026	17.7	17.8	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
	(8 m)	<0.01	<0.01	<0.05	<0.05	0.06	<0.05	0.025	0.025	18.4	18.1	<0.005	<0.0001	<0.005	<0.0001	0.008	<0.005	0.005	<0.005
	(16 m)	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	0.025	0.025	18.1	18.1	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
	Repl. 1	<0.01	<0.01	0.13	<0.05	<0.05	<0.05	0.027	0.025	17.3	17.1	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
13	Repl. 2	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	0.026	0.026	17.5	17.4	<0.005	<0.0001	<0.005	<0.0001	0.005	<0.005	0.005	<0.005
	Repl. 3	<0.01	<0.01	0.08	<0.05	<0.05	<0.05	0.026	0.025	17.2	17.7	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005
	Average	--	--	0.11	--	--	--	0.026	0.025	17.3	17.4	--	--	--	--	--	--	--	--
	S.D.	--	--	0.04	--	--	--	0.001	0.001	0.2	0.3	--	--	--	--	--	--	--	--

TABLE 7 (Cont.)

WATER QUALITY - BUCK CREEK SYSTEM
June 30, 1989

Station		TOTICP CU MG/L	TOTGF CU MG/L	DISICP CU MG/L	DISGF CU MG/L	TOTICP FE MG/L	DISICP FE MG/L	TOTICP K MG/L	DISICP K MG/L	TOTICP MG MG/L	DISICP MG MG/L	TOTICP MN MG/L	DISICP MN MG/L	TOTICP MO MG/L	DISICP MO MG/L	TOTICP NA MG/L	DISICP NA MG/L	TOTICP NI MG/L	DISICP NI MG/L
	Repl. 1	<0.005	0.0006	0.011	<0.0005	0.427	0.297	3	<2	3.9	3.6	0.034	0.026	<0.01	<0.01	2.6	2.6	<0.02	<0.02
1	Repl. 2	0.008	0.0092	<0.005	0.0006	0.518	0.278	<2	<2	3.9	3.6	0.033	0.026	<0.01	<0.01	2.7	2.5	<0.02	<0.02
	Repl. 3	<0.005	0.0019	<0.005	0.0009	0.459	0.296	2	<2	3.8	3.6	0.032	0.026	<0.01	<0.01	2.6	2.6	<0.02	<0.02
	Average	--	0.0039	--	0.0008	0.468	0.290	3	--	3.9	3.6	0.033	0.026	--	--	2.6	2.6	--	--
	S.D.	--	0.0046	--	0.0002	0.046	0.011	1	--	0.1	0.0	0.001	0.000	--	--	0.1	0.1	--	--
	Repl. 1	0.099	--	0.042	--	1.140	0.033	5	<2	22.1	21.7	0.481	0.506	<0.01	<0.01	12.1	12.8	0.03	<0.02
2	Repl. 2	0.089	--	0.050	--	1.060	0.033	4	3	22.4	21.7	0.488	0.505	<0.01	<0.01	12.4	12.8	0.03	<0.02
	Repl. 3	0.089	--	0.042	--	1.170	0.032	5	4	22.0	21.4	0.481	0.500	<0.01	<0.01	12.1	12.6	0.03	<0.02
	Average	0.092	--	0.045	--	1.123	0.033	5	4	22.2	21.6	0.483	0.504	--	--	12.2	12.7	0.03	--
	S.D.	0.006	--	0.005	--	0.057	0.001	1	1	0.2	0.2	0.004	0.003	--	--	0.2	0.1	0	--
	Repl. 1	0.007	0.0049	<0.005	0.0043	0.717	<0.005	<2	<2	8.1	5.7	0.098	<.001	<0.01	<0.01	5.0	1.9	<0.02	<0.02
3	Repl. 2	0.009	0.0060	0.005	0.0048	0.952	0.382	3	<2	8.6	7.8	0.114	0.095	<0.01	<0.01	5.3	5.0	<0.02	<0.02
	Repl. 3	0.006	0.0072	<0.005	0.0044	1.480	0.338	2	<2	8.3	7.6	0.134	0.093	<0.01	<0.01	5.2	5.0	<0.02	<0.02
	Average	0.007	0.0060	--	0.0045	1.050	0.360	3	--	8.3	7.0	0.115	0.094	--	--	5.2	4.0	--	--
	S.D.	0.002	0.0012	--	0.0003	0.391	0.031	1	--	0.3	1.2	0.018	0.001	--	--	0.2	1.8	--	--
	(1 m)	0.007	0.0049	<0.005	0.0048	0.310	0.149	<2	<2	4.6	4.4	0.067	0.006	<0.01	<0.01	3.5	3.5	<0.02	<0.02
12	(3 m)	0.007	0.0073	0.007	0.0048	0.205	0.109	<2	<2	4.4	4.2	0.020	0.003	<0.01	<0.01	3.3	3.4	<0.02	<0.02
	(8 m)	0.010	0.0044	0.006	0.0045	0.138	0.090	2	<2	4.5	4.2	0.013	0.002	<0.01	<0.01	3.4	3.3	<0.02	<0.02
	(16 m)	0.010	0.0088	0.008	0.0044	0.144	0.091	2	<2	4.5	4.2	0.011	0.002	<0.01	<0.01	3.5	3.4	<0.02	<0.02
	Repl. 1	0.006	0.0042	<0.005	0.0038	0.292	0.134	<2	<2	4.4	4.2	0.053	0.023	<0.01	<0.01	3.4	3.3	<0.02	<0.02
13	Repl. 2	<0.005	0.0020	0.008	0.0059	0.222	0.162	3	<2	4.5	4.3	0.049	0.026	<0.01	<0.01	3.4	3.5	<0.02	<0.02
	Repl. 3	<0.005	0.0024	<0.005	0.0043	0.249	0.135	<2	<2	4.4	4.2	0.051	0.025	<0.01	<0.01	3.3	3.3	<0.02	<0.02
	Average	--	0.0029	--	0.0047	0.254	0.144	--	--	4.4	4.2	0.051	0.025	--	--	3.4	3.4	--	--
	S.D.	--	0.0012	--	0.0011	0.035	0.016	--	--	0.1	0.1	0.002	0.002	--	--	0.1	0.1	--	--

TABLE 7 (Cont.)

WATER QUALITY - BUCK CREEK SYSTEM
June 30, 1989

Station		TOTICP P MG/L	DISICP P MG/L	TOTICP PB MG/L	TOTGF PB MG/L	DISICP PB MG/L	DISGF PB MG/L	TOTICP SB MG/L	DISICP SB MG/L	TOTICP SI MG/L	DISICP SI MG/L	TOTICP SN MG/L	DISICP SN MG/L	TOTICP SR MG/L	DISICP SR MG/L	TOTICP ZN MG/L	DISICP ZN MG/L
	Repl. 1	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	<0.05	<0.05	4.83	4.58	<0.05	<0.05	0.133	0.137	0.014	<0.002
1	Repl. 2	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	<0.05	<0.05	5.11	4.60	<0.05	<0.05	0.135	0.136	0.015	<0.002
	Repl. 3	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	<0.05	<0.05	4.92	4.66	<0.05	<0.05	0.129	0.136	0.015	0.048
	Average	--	--	--	--	--	--	--	--	4.95	4.61	--	--	0.132	0.136	0.015	--
	S.D.	--	--	--	--	--	--	--	--	0.14	0.04	--	--	0.003	0.001	0.001	--
	Repl. 1	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	0.07	0.05	6.53	4.39	<0.05	<0.05	6.450	7.140	0.100	0.041
2	Repl. 2	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	0.06	<0.05	6.20	4.37	<0.05	<0.05	6.580	7.140	0.094	0.038
	Repl. 3	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	0.06	0.06	6.63	4.34	<0.05	<0.05	6.400	7.010	0.096	0.038
	Average	--	--	--	--	--	--	0.06	0.06	6.45	4.37	--	--	6.477	7.097	0.097	0.039
	S.D.	--	--	--	--	--	--	0.01	0.01	0.23	0.03	--	--	0.093	0.075	0.003	0.002
	Repl. 1	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	<0.05	<0.05	5.06	6.07	<0.05	<0.05	1.240	0.089	0.019	<0.002
3	Repl. 2	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	<0.05	<0.05	5.71	4.73	<0.05	<0.05	1.300	1.320	0.019	<0.002
	Repl. 3	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	<0.05	<0.05	6.68	4.55	<0.05	<0.05	1.260	1.290	0.020	0.003
	Average	--	--	--	--	--	--	--	--	5.82	5.12	--	--	1.267	0.900	0.019	--
	S.D.	--	--	--	--	--	--	--	--	0.82	0.83	--	--	0.031	0.702	0.001	--
	(1 m)	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.005	<0.05	<0.05	4.57	4.00	<0.05	<0.05	0.305	0.314	0.033	0.016
12	(3 m)	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.005	<0.05	<0.05	4.17	3.69	<0.05	<0.05	0.304	0.311	0.022	0.004
	(8 m)	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.005	<0.05	<0.05	3.60	3.20	<0.05	<0.05	0.328	0.331	0.017	0.005
	(16 m)	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.005	<0.05	<0.05	3.56	3.27	<0.05	<0.05	0.327	0.337	0.021	0.004
	Repl. 1	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	<0.05	<0.05	3.08	2.56	<0.05	<0.05	0.303	0.311	0.011	<0.002
13	Repl. 2	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	<0.05	<0.05	2.78	2.65	<0.05	<0.05	0.304	0.320	0.011	0.004
	Repl. 3	<0.1	<0.1	<0.05	<0.0006	<0.05	<0.0005	<0.05	<0.05	2.90	2.61	<0.05	<0.05	0.300	0.313	0.012	<0.002
	Average	--	--	--	--	--	--	--	--	2.92	2.61	--	--	0.302	0.315	0.011	--
	S.D.	--	--	--	--	--	--	--	--	0.15	0.05	--	--	0.002	0.005	0.001	--

TABLE 7 (Cont.):

WATER QUALITY - BUCK CREEK SYSTEM
June 30, 1989

Station		ALK MG/L	DISICP HC MG/L	DISICP HT MG/L	FR MG/L	NFR MG/L	PH REL.U.	SO4 MG/L	TIC MG/L	TOC MG/L
	Repl. 1	47.6	48.4	49.3	95	<5	8.1	5	9	15
1	Repl. 2	47.6	48.7	49.6	96	18	8.1	5	9	15
	Repl. 3	94.2	48.8	49.8	98	6	8.1	4	8	16
	Average	63.1	48.6	49.6	96	12	8.1	5	9	15
	S.D.	26.9	0.2	0.3	2	8	0	1	1	1
	Repl. 1	73.3	520	530	884	23	8.3	370	16	4
2	Repl. 2	74.7	518	528	888	22	8.3	420	15	11
	Repl. 3	74.7	515	525	886	<5	8.3	410	16	9
	Average	74.2	518	528	886	23	8.3	400	16	8
	S.D.	0.8	3	3	2	1	0	26	1	4
	Repl. 1	55.3	179	179	250	50	8.2	77	11	15
3	Repl. 2	55.3	146	149	249	21	8.2	86	11	16
	Repl. 3	55.3	143	145	250	20	8.2	88	11	18
	Average	55.3	156	158	250	30	8.2	84	11	16
	S.D.	0.0	20	19	1	17	0	6	0	2
	(1 m)	36.9	64.1	64.8	124	<5	8.0	27	8	21
12	(3 m)	34.9	62.0	62.7	115	<5	8.0	29	7	22
	(8 m)	36.9	62.5	63.1	120	<5	8.1	28	7	21
	(16 m)	41.7	62.4	63.0	121	<5	8.1	29	6	23
	Repl. 1	35.9	59.8	60.5	116	<5	8.0	27	6	22
13	Repl. 2	35.9	61.2	62.1	116	<5	8.0	28	7	21
	Repl. 3	35.9	61.7	62.4	119	<5	8.0	24	6	22
	Average	35.9	60.9	61.7	117	--	8	26	6	22
	S.D.	0.0	1.0	1.0	2	--	0	2	1	1

4.1.4 **<u>June 15-17, 1990</u>.** The water quality results are presented in Table 9, and the lake profile data is in Table 10.

The thermocline could be found between 6 and 8 metres depth at Stations 11 and 12. At Station 8, the thermocline was disturbed due to strong west-east winds. Warmer surface waters migrated toward the eastern part of the lake and lowered the thermocline to a depth of 11 to 12 metres. This effect of internal seiche has been reported before (Hutchinson, 1957).

Lake pH varied from 7.0 in the hypolimnion to 8.1 in the epilimnion. Conductivities were fairly constant varying between 33.3 and 36.8 µmhos/cm. Conductivity was reduced from earlier surveys which had levels on the order of 180 µmhos/cm (Godin, 1988).

4.2 Sediments

4.2.1 **<u>Lake Surface Sediment Collection</u>.** Sediment traps were located in the lake in May 1988 at Stations 5, 7, 8, 9, and 11. Retrieval was performed on June 22, 1988. Sediment was collected by an Eckman dredge at Stations 4, 8, 9, 10, and 12 on July 2, 1989, and Stations 7, 8, 10, 11, and 12, on June 16, 1990. Tables 11, 12, and 13 show the results of these samples.

Sediment arsenic content greatly increased from 1987 to 1988. This was partly due to the improved detection limit of the ICAP procedure which was changed from 50 µg/g in 1987 to 8 µg/g in 1988. The arsenic content of the reference material averaged 11.6 ± 1.3 µg/g. In 1989, the determination of arsenic in the reference material was <8 µg/g, indicating not all arsenic in the sample was accounted for. It is difficult to determine if the sediment arsenic content showed significant elevation due to these problems with the reference material or some other influence.

name and unit conventions if possible (5 pages)

TABLE 9 :

WATER QUALITY - BUCK CREEK SYSTEM
June 15-17, 1990

Station Number		TOTICP AG MG/L	DISICP AG MG/L	TOTICP AL MG/L	DISICP AL MG/L	TOTICP AS MG/L	DISICP AS MG/L	TOTICP B MG/L	DISICP B MG/L	TOTICP BA MG/L	DISICP BA MG/L	TOTICP BE MG/L	DISICP BE MG/L	TOTICP CA MG/L	DISICP CA MG/L
	Repl. 1	<0.01	<0.01	0.56	0.11	<0.05	<0.05	0.01	<0.01	0.033	0.026	<0.001	<0.001	11.6	11.6
	Repl. 2	<0.01	<0.01	0.54	0.09	<0.05	<0.05	0.01	<0.01	0.032	0.026	<0.001	<0.001	11.7	11.7
1	Repl. 3	<0.01	<0.01	0.58	0.08	<0.05	<0.05	<0.01	<0.01	0.033	0.026	<0.001	<0.001	11.6	11.6
	Average	---	---	0.56	0.09	---	---	0.01	---	0.033	0.026	---	---	11.6	11.6
	S.D.	---	---	0.02	0.02	---	---	0.00	---	0.001	0.000	---	---	0.1	0.1
2	Repl. 1	<0.01	<0.01	0.43	0.08	<0.05	<0.05	0.02	0.02	0.055	0.047	<0.001	<0.001	296	300
	Repl. 1	<0.01	<0.01	0.47	0.08	<0.05	<0.05	<0.01	<0.01	0.043	0.037	<0.001	<0.001	61.4	61.7
	Repl. 2	<0.01	<0.01	0.41	0.06	<0.05	<0.05	0.02	<0.01	0.041	0.037	<0.001	<0.001	61.4	61.7
3	Repl. 3	<0.01	<0.01	0.38	0.06	<0.05	<0.05	0.02	<0.01	0.042	0.036	<0.001	<0.001	61.8	60.8
	Average	---	---	0.42	0.07	---	---	0.02	---	0.042	0.037	---	---	61.5	61.4
	S.D.	---	---	0.05	0.01	---	---	0.00	---	0.001	0.001	---	---	0.2	0.5
	surface	<0.01	<0.01	0.15	<0.05	<0.05	<0.05	<0.01	<0.01	0.030	0.027	<0.001	<0.001	29.7	30.2
8	12 m	<0.01	<0.01	0.12	<0.05	<0.05	<0.05	0.02	<0.01	0.032	0.027	<0.001	<0.001	29.5	30.2
	16 m	<0.01	<0.01	0.15	0.05	<0.05	<0.05	<0.01	<0.01	0.031	0.029	<0.001	<0.001	25.3	26.3
	surface	<0.01	<0.01	0.46	<0.05	<0.05	<0.05	<0.01	<0.01	0.048	0.027	<0.001	<0.001	36.9	28.9
11	10 m	<0.01	<0.01	0.15	<0.05	<0.05	<0.05	<0.01	<0.01	0.031	0.028	<0.001	<0.001	26.2	26.4
	16 m	<0.01	<0.01	0.22	<0.05	<0.05	<0.05	0.01	<0.01	0.039	0.033	<0.001	<0.001	24.8	28.5
	surface	<0.01	<0.01	0.12	<0.05	<0.05	<0.05	0.01	<0.01	0.030	0.027	<0.001	<0.001	28.1	28.9
12	10 m	<0.01	<0.01	0.14	<0.05	<0.05	<0.05	0.02	<0.01	0.034	0.028	<0.001	<0.001	25.7	26.8
	19 m	<0.01	<0.01	0.92	<0.05	<0.05	<0.05	0.02	<0.01	0.051	0.037	<0.001	<0.001	25.1	26.0
	Repl. 1	<0.01	<0.01	0.16	0.05	<0.05	<0.05	0.02	<0.01	0.032	0.027	<0.001	<0.001	27.3	28.0
	Repl. 2	<0.01	<0.01	0.15	<0.05	<0.05	<0.05	0.02	<0.01	0.030	0.027	<0.001	<0.001	27.4	28.1
13	Repl. 3	<0.01	<0.01	0.16	<0.05	<0.05	<0.05	<0.01	<0.01	0.030	0.027	<0.001	<0.001	27.1	28.0
	Average	---	---	0.16	---	---	---	0.02	---	0.031	0.027	---	---	27.3	28.0
	S.D.	---	---	0.01	---	---	---	0.00	---	0.001	0.000	---	---	0.2	0.1

TABLE 9 (Cont.)

WATER QUALITY - BUCK CREEK SYSTEM
June 15-17, 1990

Station Number		TOTICP CD MG/L	TOTGF CD MG/L	DISICP CD MG/L	DISGF CD MG/L	TOTICP CO MG/L	DISICP CO MG/L	TOTICP CR MG/L	DISICP CR MG/L	TOTICP CU MG/L	DISICP CU MG/L	TOTICP FE MG/L	DISICP FE MG/L	TOTICP K MG/L	DISICP K MG/L	TOTICP MG MG/L	DISICP MG MG/L
	Repl. 1	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	0.668	0.288	<2	<2	3.3	3.3
	Repl. 2	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.008	<0.005	<0.005	<0.005	0.650	0.276	<2	<2	3.3	3.3
1	Repl. 3	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.676	0.259	<2	<2	3.3	3.3
	Average	---	---	---	---	---	---	0.007	---	---	---	0.665	0.274	---	---	3.3	3.3
	S.D.	---	---	---	---	---	---	0.001	---	---	---	0.013	0.015	---	---	0.0	0.0
2	Repl. 1	<0.005	0.0014	<0.005	0.0014	<0.005	<0.005	0.011	<0.005	0.028	0.017	0.345	0.035	3	3	56.0	55.3
	Repl. 1	<0.005	0.0002	<0.005	0.0002	<0.005	<0.005	0.007	<0.005	0.008	<0.005	0.825	0.353	<2	<2	12.1	12.2
	Repl. 2	<0.005	0.0002	<0.005	0.0002	<0.005	<0.005	0.010	<0.005	0.008	<0.005	0.758	0.354	<2	<2	12.0	12.2
3	Repl. 3	<0.005	0.0002	<0.005	0.0002	<0.005	<0.005	0.010	<0.005	0.010	<0.005	0.734	0.347	<2	<2	11.8	12.1
	Average	---	0.0002	---	0.0002	---	---	0.009	---	0.009	---	0.772	0.351	---	---	12.0	12.2
	S.D.	---	0	---	0	---	---	0.002	---	0.001	---	0.047	0.004	---	---	0.2	0.1
	surface	<0.005	0.0003	<0.005	<0.0001	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.482	0.110	<2	<2	6.4	6.5
8	12 m	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	0.009	<0.005	0.010	<0.005	0.226	0.110	<2	<2	6.4	6.5
	16 m	<0.005	0.0003	<0.005	<0.0001	<0.005	<0.005	0.008	<0.005	<0.005	<0.005	0.309	0.142	<2	<2	5.8	5.9
	surface	<0.005	0.0026	<0.005	<0.0001	<0.005	<0.005	0.011	<0.005	0.065	<0.005	0.525	0.104	<2	<2	6.6	6.3
11	10 m	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.010	<0.005	0.006	<0.005	0.286	0.142	<2	<2	5.7	5.9
	16 m	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	0.005	<0.005	0.005	<0.005	0.413	0.165	<2	<2	5.7	5.8
	surface	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	0.011	<0.005	0.007	<0.005	0.214	0.108	<2	<2	6.3	6.3
12	10 m	<0.005	0.0002	<0.005	<0.0001	<0.005	<0.005	0.008	<0.005	0.006	<0.005	0.269	0.131	<2	<2	5.8	6.0
	19 m	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.010	<0.005	0.007	<0.005	1.620	0.223	<2	<2	5.8	5.8
	Repl. 1	<0.005	0.0001	<0.005	<0.0001	0.005	<0.005	0.008	<0.005	0.006	<0.005	0.263	0.118	<2	<2	6.0	6.2
	Repl. 2	<0.005	<0.0001	<0.005	<0.0001	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	0.254	0.116	<2	<2	6.1	6.2
13	Repl. 3	<0.005	0.0001	<0.005	<0.0001	<0.005	<0.005	0.010	<0.005	<0.005	<0.005	0.275	0.115	<2	<2	6.1	6.2
	Average	---	---	---	---	---	---	0.008	---	---	---	0.264	0.116	---	---	6.1	6.2
	S.D.	---	---	---	---	---	---	0.002	---	---	---	0.011	0.002	---	---	0.1	0.0

TABLE 9 (Cont.)

WATER QUALITY - BUCK CREEK SYSTEM
June 15-17, 1990

Station Number		TOTICP MN MG/L	DISICP MN MG/L	TOTICP MO MG/L	DISICP MO MG/L	TOTICP NA MG/L	DISICP NA MG/L	TOTICP NI MG/L	DISICP NI MG/L	TOTICP P MG/L	DISICP P MG/L	TOTICP PB MG/L	TOTGF PB MG/L	DISICP PB MG/L	DISGF PB MG/L	TOTICP SB MG/L	DISICP SB MG/L
	Repl. 1	0.036	0.025	<0.01	<0.01	2.4	2.3	<0.02	<0.02	<0.1	<0.1	<0.05	0.0025	<0.05	<0.0005	<0.05	<0.05
	Repl. 2	0.035	0.023	<0.01	<0.01	2.4	2.4	<0.02	<0.02	<0.1	<0.1	<0.05	0.0031	<0.05	<0.0005	<0.05	<0.05
1	Repl. 3	0.037	0.022	<0.01	<0.01	2.4	2.4	<0.02	<0.02	<0.1	<0.1	<0.05	0.0025	<0.05	0.0006	<0.05	<0.05
	Average	0.036	0.023	---	---	2.4	2.4	---	---	---	---	---	0.0027	---	---	---	---
	S.D.	0.001	0.002	---	---	0.0	0.1	---	---	---	---	---	0.0003	---	---	---	---
2	Repl. 1	0.241	0.224	<0.01	<0.01	11.9	12.1	<0.02	<0.02	<0.1	<0.1	<0.05	0.0041	<0.05	<0.0005	<0.05	<0.05
	Repl. 1	0.120	0.100	<0.01	<0.01	4.2	4.3	<0.02	<0.02	<0.1	<0.1	<0.05	0.0030	<0.05	0.0007	<0.05	<0.05
	Repl. 2	0.117	0.100	<0.01	<0.01	4.2	4.3	<0.02	<0.02	<0.1	<0.1	<0.05	0.0043	<0.05	0.0011	<0.05	<0.05
3	Repl. 3	0.112	0.099	<0.01	<0.01	4.1	4.3	<0.02	<0.02	<0.1	<0.1	<0.05	0.0036	<0.05	0.0016	<0.05	<0.05
	Average	0.116	0.100	---	---	4.2	4.3	---	---	---	---	---	0.0036	---	0.0011	---	---
	S.D.	0.004	0.001	---	---	0.1	0.0	---	---	---	---	---	0.0007	---	0.0005	---	---
	surface	0.033	0.003	<0.01	<0.01	3.5	3.6	<0.02	<0.02	<0.1	<0.1	<0.05	0.0032	<0.05	0.0007	<0.05	<0.05
8	12 m	0.030	0.002	<0.01	<0.01	3.5	3.6	<0.02	<0.02	<0.1	<0.1	<0.05	0.0037	<0.05	0.0011	<0.05	<0.05
	16 m	0.056	0.007	<0.01	<0.01	3.6	3.6	<0.02	<0.02	<0.1	<0.1	<0.05	0.0024	<0.05	0.0009	<0.05	<0.05
	surface	0.099	0.002	<0.01	<0.01	6.4	3.6	<0.02	<0.02	0.2	<0.1	<0.05	0.0298	<0.05	0.0010	<0.05	<0.05
11	10 m	0.047	0.004	<0.01	<0.01	3.5	3.6	<0.02	<0.02	<0.1	<0.1	<0.05	0.0019	<0.05	0.0011	<0.05	<0.05
	16 m	0.122	0.034	<0.01	<0.01	3.6	3.7	<0.02	<0.02	<0.1	<0.1	<0.05	0.0029	<0.05	0.0008	<0.05	<0.05
	surface	0.028	0.002	<0.01	<0.01	3.5	3.6	<0.02	<0.02	<0.1	<0.1	<0.05	0.0056	<0.05	0.0014	<0.05	<0.05
12	10 m	0.040	0.003	<0.01	<0.01	3.5	3.6	<0.02	<0.02	<0.1	<0.1	<0.05	0.0021	<0.05	0.0007	<0.05	<0.05
	19 m	0.203	0.121	<0.01	<0.01	3.7	3.6	<0.02	<0.02	<0.1	<0.1	<0.05	0.0095	<0.05	0.0008	<0.05	<0.05
	Repl. 1	0.045	0.010	<0.01	<0.01	3.5	3.6	<0.02	<0.02	<0.1	<0.1	<0.05	0.0044	<0.05	0.0011	<0.05	<0.05
	Repl. 2	0.045	0.011	<0.01	<0.01	3.5	3.6	<0.02	<0.02	<0.1	<0.1	<0.05	0.0021	<0.05	0.0012	<0.05	<0.05
13	Repl. 3	0.047	0.011	<0.01	<0.01	3.5	3.6	<0.02	<0.02	<0.1	<0.1	<0.05	0.0016	<0.05	0.0011	<0.05	<0.05
	Average	0.046	0.011	---	---	3.5	3.6	---	---	---	---	---	0.0027	---	0.0011	---	---
	S.D.	0.001	0.001	---	---	0.0	0.0	---	---	---	---	---	0.0015	---	0.0001	---	---

TABLE 9 (Cont.):

WATER QUALITY - BUCK CREEK SYSTEM
June 15-17, 1990

Station Number		TOTICP SE MG/L	DISICP SE MG/L	TOTICP SI MG/L	DISICP SI MG/L	TOTICP SN MG/L	DISICP SN MG/L	TOTICP SR MG/L	DISICP SR MG/L	TOTICP TI MG/L	DISICP TI MG/L	TOTICP V MG/L	DISICP V MG/L	TOTICP ZN MG/L	DISICP ZN MG/L
	Repl. 1	<0.05	<0.05	7.35	6.21	<0.05	<0.05	0.129	0.124	0.009	<0.002	<0.01	<0.01	0.012	<0.002
	Repl. 2	<0.05	<0.05	7.28	6.23	<0.05	<0.05	0.128	0.125	0.007	<0.002	<0.01	<0.01	<0.002	<0.002
1	Repl. 3	<0.05	<0.05	7.32	6.19	<0.05	<0.05	0.128	0.125	0.008	<0.002	<0.01	<0.01	<0.002	<0.002
	Average	---	---	7.32	6.21	---	---	0.128	0.125	0.008	---	---	---	---	---
	S.D.	---	---	0.04	0.02	---	---	0.001	0.001	0.001	---	---	---	---	---
2	Repl. 1	<0.05	<0.05	4.16	3.52	<0.05	<0.05	4.16	4.06	<0.002	<0.002	<0.01	<0.01	0.071	0.048
	Repl. 1	<0.05	<0.05	6.90	5.90	<0.05	<0.05	0.902	0.884	0.004	<0.002	<0.01	<0.01	0.017	0.003
	Repl. 2	<0.05	<0.05	6.75	5.90	<0.05	<0.05	0.896	0.881	<0.002	<0.002	<0.01	<0.01	0.004	0.002
3	Repl. 3	<0.05	<0.05	6.52	5.83	<0.05	<0.05	0.887	0.871	<0.002	<0.002	<0.01	<0.01	0.008	0.004
	Average	---	---	6.72	5.88	---	---	0.895	0.879	---	---	---	---	0.010	0.003
	S.D.	---	---	0.19	0.04	---	---	0.008	0.007	---	---	---	---	0.007	0.001
	surface	<0.05	<0.05	5.1	4.8	<0.05	<0.05	0.476	0.472	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
8	12 m	<0.05	<0.05	5.01	4.79	<0.05	<0.05	0.473	0.468	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	16 m	<0.05	<0.05	5.38	5.07	<0.05	<0.05	0.443	0.441	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	surface	<0.05	<0.05	5.48	4.73	<0.05	<0.05	0.478	0.457	<0.002	<0.002	<0.01	<0.01	0.379	<0.002
11	10 m	<0.05	<0.05	5.29	5.07	<0.05	<0.05	0.441	0.44	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	16 m	<0.05	<0.05	5.69	5.18	<0.05	<0.05	0.441	0.44	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	surface	<0.05	<0.05	5.03	4.75	<0.05	<0.05	0.468	0.459	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
12	10 m	<0.05	<0.05	5.19	4.93	<0.05	<0.05	0.447	0.443	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	19 m	<0.05	<0.05	7.88	5.23	<0.05	<0.05	0.45	0.434	0.015	<0.002	<0.01	<0.01	0.007	<0.002
	Repl. 1	<0.05	<0.05	5.06	4.63	<0.05	<0.05	0.444	0.439	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	Repl. 2	<0.05	<0.05	5.09	4.65	<0.05	<0.05	0.454	0.444	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
13	Repl. 3	<0.05	<0.05	5.08	4.62	<0.05	<0.05	0.449	0.446	<0.002	<0.002	<0.01	<0.01	<0.002	<0.002
	Average	---	---	5.08	4.63	---	---	0.449	0.443	---	---	---	---	---	---
	S.D.	---	---	0.02	0.02	---	---	0.005	0.004	---	---	---	---	---	---

TABLE 9 (Cont.):

WATER QUALITY - BUCK CREEK SYSTEM
June 15-17, 1990

Station Number		ALK MG/L	PH REL.U.	DISICP HC MG/L	DISICP HT MG/L	SO4 MG/L	TIC MG/L	TOC MG/L	DIC MG/L	DOC MG/L	TR MG/L	NFR MG/L
	Repl. 1	41	7.7	42.7	44.0	4.4	9	18	9	18	110	9
	Repl. 2	41	7.7	42.8	44.0	4.2	9	18	9	17	100	9
1	Repl. 3	41	7.7	42.5	43.6	4.0	9	18	9	18	110	11
	Average	41	7.7	42.7	43.9	4.2	9	18	9	18	107	10
	S.D.	0	0.0	0.2	0.2	0.2	0	0	0	1	6	1
2	Repl. 1	52	7.8	976	982	897	12	8	8	9	1570	<5
	Repl. 1	44	7.7	204	206	146	11	16	10	16	340	7
	Repl. 2	44	7.7	204	206	158	11	16	10	16	340	<5
3	Repl. 3	44	7.7	201	203	144	10	16	10	15	350	<5
	Average	44	7.7	203	205	149	11	16	10	16	343	---
	S.D.	0	0.0	1.7	1.7	7.6	1	0	0	1	6	---
	surface	36	7.9	102	103	67.7	8	18	7	16	180	<5
8	12 m	37	7.7	102	103	67.8	8	16	8	16	180	<5
	16 m	38	7.8	89.9	90.9	56.7	10	16	8	16	180	<5
	surface	36	7.7	97.9	98.8	64.4	8	16	7	16	180	<5
11	10 m	38	7.7	90.1	91.2	56.3	10	15	8	17	160	<5
	16 m	38	7.5	88.5	89.5	54.0	10	15	8	15	160	<5
	surface	37	7.7	98.1	99.0	64.3	8	17	8	15	180	<5
12	10 m	37	7.6	91.5	92.5	56.4	9	16	9	16	170	<5
	19 m	38	7.5	88.7	90.0	54.4	11	15	8	15	200	29
	Repl. 1	37	7.7	95.3	96.3	54.6	8	18	7	15	180	6
	Repl. 2	37	7.7	95.6	96.5	58.4	8	17	8	16	170	<5
13	Repl. 3	36	7.7	95.6	96.5	60.6	8	17	7	16	180	6
	Average	37	7.7	95.5	96.4	57.9	8	17	7	16	177	6
	S.D.	1	0.0	0.2	0.1	3.0	0	1	1	1	6	0

TABLE 10: GOOSLY LAKE TEMPERATURE CONDUCTIVITY-PROFILE - June 15-16, 1990

Station 8	Depth (m)	Conductivity (μmhos/cm)	Temperature (°C)	pH
	1	34.2	13.4	7.7
	2	33.9	13.4	7.7
	3	33.9	13.4	7.7
	4	33.9	13.4	7.8
	5	33.9	13.3	7.8
	6	33.8	13.2	7.6
	7	33.8	11.9	7.5
	8	33.5	11.8	7.4
	9	34.2	10.4	7.3
	10	33.9	9.8	7.2
	11	33.9	9.2	7.1
	12	33.8	8.0	7.0
	13	33.6	7.8	7.0
	14	33.7	7.6	7.0
	15	33.6	7.2	7.0
	16	33.5	6.6	7.0

Station 11	Depth (m)	Conductivity (μmhos/cm)	Temperature (°C)	pH
	1	36.8	12.7	7.7
	2	34.5	12.3	7.6
	3	34.3	12.0	7.6
	4	34.1	11.9	7.5
	5	34.1	11.8	7.5
	6	34.2	11.0	7.4
	7	34.4	9.5	7.2
	8	33.9	7.3	7.2
	9	33.4	6.8	7.1
	10	33.3	6.3	7.2
	11	33.3	6.2	7.1
	15	33.3	5.6	7.1
	16	33.3	5.6	7.0

Station 12	Depth (m)	Conductivity (μmhos/cm)	Temperature (°C)	pH
	1	36.5	13.1	7.6
	2	34.7	13.0	8.1
	3	34.2	12.9	7.8
	4	33.9	12.3	7.7
	5	34.2	11.7	7.6
	6	34.5	11.4	7.5
	7	34.6	10.4	7.4
	8	34.6	9.8	7.3
	9	34.4	8.9	7.3
	10	33.5	8.7	7.0
	15	33.0	7.0	7.0
	18	33.7	5.5	7.0
	19	33.7	5.5	7.0

Name and unit conventions, if possible. (Tables 11-13 inclusive)

TABLE 11:

SEDIMENT QUALITY - GOOSLY LAKE
June 22, 1988

Lake Station Number	SEDICP AG UG/G	SEDGF AG UG/G	SEDICP AL UG/G	SEDICP AS UG/G	SEDICP BA UG/G	SEDICP CA UG/G	SEDICP CD UG/G	SEDGF CD UG/G	SEDICP CO UG/G	SEDICP CR UG/G	SEDICP CU UG/G	SEDICP FE UG/G	SEDWG HG UG/G	SEDICP MG UG/G	SEDICP MN UG/G
5	<2	0.51	28200	50	523	8800	0.6	0.8	20	32.2	90	62200	0.409	7100	3670
7	<2	0.60	28900	50	549	9800	0.8	1.0	16	32.1	100	64200	0.372	7300	5290
8	<2	0.62	29800	<50	492	9000	1.0	0.9	20	33.8	100	57200	0.447	7400	2760
9	<2	0.61	29900	<50	465	10000	0.5	0.8	20	33.6	88	60100	0.332	7600	4280
11	<2	0.68	32200	60	519	11000	1.0	1.0	20	32.1	100	62800	0.374	7800	5470
Average	--	0.60	29800	53	510	9720	0.8	0.9	19	32.8	96	61300	0.387	7440	4294
S.D.	--	0.06	1512	6	32	879	0.2	0.1	2	0.9	6	2726	0.043	270	1131

Lake Station Number	SEDICP MO UG/G	SEDICP NA UG/G	SEDICP NI UG/G	SEDICP P UG/G	SEDICP PB UG/G	SEDICP SI UG/G	SEDICP SR UG/G	SEDICP SN UG/G	SEDICP TI UG/G	SEDICP V UG/G	SEDICP ZN UG/G	SFR MG/KG	SVR MG/KG	TN UG/G
5	<5	700	33.6	3100	37	2030	150	<8	967	77.7	249	853000	147000	4700
7	<5	700	36.9	3500	51	2200	184	<8	805	75.9	288	830000	170000	5800
8	<5	700	37.8	3000	50	1960	159	<8	884	77.4	363	840000	160000	5600
9	<5	800	37.8	3200	46	1790	182	<8	971	79.5	294	840000	160000	5400
11	<5	400	37.0	3600	65	1790	203	<8	836	75.9	300	822000	178000	6600
Average	--	660	36.6	3280	50	1954	176	--	893	77.3	299	837000	163000	5620
S.D.	--	152	1.7	259	10	173	21	--	75	1.5	41	11705	11705	687

TABLE 12 :

SEDIMENT QUALITY - BUCK CREEK SYSTEM
July 2, 1989

Station		SEDICP AG UG/G	SEDICP AL UG/G	SEDICP AS UG/G	SEDICP CA UG/G	SEDICP CD UG/G	SEDICP CR UG/G	SEDICP CU UG/G	SEDICP FE UG/G	SEDHG HG UG/G	SEDICP K UG/G	SEDICP MG UG/G	SEDICP MN UG/G	SEDICP MO UG/G
	Repl. 1	<2	15600	10	8230	<0.8	38.5	<0.8	34300	0.110	1000	6090	1700	<2
1	Repl. 2	<2	14400	<8	7330	<0.8	37.9	<0.8	31600	0.130	1000	5570	1150	<2
	Repl. 3	<2	14400	10	7600	<0.8	40.7	<0.8	32900	0.095	1000	6280	1190	<2
	Repl. 4	<2	14400	10	7770	<0.8	40.6	<0.8	34400	0.120	1000	6560	1250	<2
	Average	--	14750	10	7733	--	39.4	--	33300	0.114	1000	6125	1323	--
	S.D.	--	700	0	378	--	1.4	--	1324	0.015	0	417	255	--
	Repl. 1	4	19500	87	7880	3.9	28.1	527.0	43800	0.160	3200	6120	805	7
2	Repl. 2	4	19000	86	7670	3.7	26.8	538.0	42900	0.204	2800	6040	800	8
	Repl. 3	4	19300	85	7850	3.9	28.5	545.0	44100	0.160	3100	6170	816	9
	Repl. 4	5	20800	99	8170	4.0	30.1	579.0	45900	0.140	3500	6470	832	8
	Average	4	19650	89	7893	3.9	28.4	547.3	44175	0.166	3150	6200	813	8
	S.D.	1	794	7	207	0.1	1.4	22.4	1258	0.027	289	188	14	1
	Repl. 1	<2	15000	19	9100	1.0	36.3	35.3	39200	0.130	1000	6010	1140	<2
3	Repl. 2	<2	12400	10	7670	1.0	34.5	9.8	34700	0.093	900	5480	636	<2
	Repl. 3	<2	15100	21	8530	1.0	37.1	32.5	36600	1.380	1000	5590	1040	<2
	Repl. 4	<2	13600	10	8200	<0.8	35.9	25.0	35600	0.150	1000	5600	812	<2
	Average	--	14025	15	8375	1.0	36.0	25.7	36525	0.438	975	5670	907	--
	S.D.	--	1282	6	599	0.0	1.1	11.4	1945	0.628	50	233	227	--
4	grab	<2	27000	49	9950	1.0	36.2	95.2	62600	0.596	2600	7600	3260	<2
8	grab	<2	18300	34	9120	0.9	36.1	64.9	47200	0.300	1600	6370	1560	<2
9	grab	<2	29700	49	9690	<0.8	38.0	92.5	66000	0.465	2700	8000	3700	<2
10	grab	<2	28800	53	10500	<0.8	49.7	88.2	66000	1.030	2700	7950	4030	2
12	grab	<2	31200	32	8260	<0.8	38.9	90.3	68100	0.678	2800	8530	3420	<2
	Average	--	27000	43	9504	1.0	39.8	86.2	61980	0.614	2480	7690	3194	--
	S.D.	--	5096	10	854	0.1	5.7	12.2	8494	0.273	497	809	959	--
	Repl. 1	<2	14400	10	9190	0.8	43.3	1.0	30400	0.120	1000	7070	928	<2
	Repl. 2	<2	14400	10	9780	2.0	37.4	9.6	28700	0.120	1000	6440	1100	<2
13	Repl. 3	<2	15700	10	9140	<0.8	45.2	<0.8	33800	0.049	1000	7800	566	<2
	Repl. 4	<2	14000	9	9510	0.9	40.7	1.0	29800	0.120	1000	7270	876	<2
	Average	--	14625	10	9405	1.2	41.7	3.9	30675	0.102	1000	7145	868	--
	S.D.	--	741	1	299	0.7	3.4	5.0	2199	0.036	0	562	223	--
	nbs 1645	<2	5820	76	29300	8.5	29100	112.0	95800	0.951	1000	7330	763	19
	nbs 1645	<2	5700	76	29000	8.5	27800	110.0	90500	0.678	700	7290	743	20
	nbs 1645	<2	6010	71	28700	8.1	28100	112.0	95600	0.861	800	7360	740	18
	nbs 1646	<2	20400	<8	4210	<0.8	46.2	<0.8	26200	0.075	4900	8870	255	<2
	nbs 1646	<2	20200	<8	4200	<0.8	46.4	<0.8	26700	0.074	4800	9000	259	2
	nbs 1646	<2	20900	<8	4180	<0.8	46.8	<0.8	26400	0.082	5000	8930	256	2

TABLE 12 (Cont.)

SEDIMENT QUALITY - BUCK CREEK SYSTEM
July 2, 1989

Station		SEDICP NA UG/G	SEDICP NI UG/G	SEDICP P UG/G	SEDICP PB UG/G	SEDICP SI UG/G	SEDICP SN UG/G	SEDICP SR UG/G	SEDICP TI UG/G	SEDICP V UG/G	SEDICP ZN UG/G	SFR MG/KG	SVR MG/KG
	Repl. 1	330	27	1500	10	720	<8	101	1030	87	109	939000	60500
1	Repl. 2	380	25	1400	10	693	<8	90.6	1080	81	103	951000	48600
	Repl. 3	340	28	1500	10	725	<8	89.1	1010	84	101	947000	53100
	Repl. 4	320	30	1500	10	836	<8	90.6	1040	88	110	949000	50600
	Average	343	28	1475	10	744	--	92.8	1040	85	106	946500	53200
	S.D.	26	2	50	0	63	--	5.5	29	3	4	5260	5203
	Repl. 1	340	38	1730	176	684	<8	205	559	74	573	952000	48000
2	Repl. 2	300	38	1670	175	741	<8	205	524	70	566	950000	49700
	Repl. 3	320	40	1710	180	783	<8	210	553	74	579	948000	51800
	Repl. 4	320	41	1770	189	764	<8	219	579	79	599	951000	49400
	Average	320	39	1720	180	743	--	210	554	74	579	950250	49725
	S.D.	16	2	42	6	43	--	7	23	4	14	1708	1569
	Repl. 1	350	30	1860	19	646	<8	170	1020	88	160	923000	77300
3	Repl. 2	260	25	1790	10	644	<8	117	1060	84	133	958000	41600
	Repl. 3	290	27	1730	20	714	<8	162	1010	85	152	929000	70700
	Repl. 4	280	27	1780	17	786	<8	148	978	82	143	944000	56400
	Average	295	27	1790	17	698	--	149	1017	85	147	938500	61500
	S.D.	39	2	54	5	67	--	23	34	3	12	15716	15878
4	grab	420	37	2840	38	1140	<8	176	675	100	391	849000	151000
8	grab	330	30	2280	23	779	<8	149	887	85	162	904000	95500
9	grab	620	38	3190	31	1320	<8	174	771	110	436	840000	160000
10	grab	1200	51	2920	64	1280	31	177	695	100	479	832000	168000
12	grab	540	43	2660	36	1460	<8	128	702	110	358	859000	141000
	Average	622	40	2778	38	1196	--	161	746	101	365	856800	143100
	S.D.	342	8	338	15	259	--	22	87	10	122	28244	28453
	Repl. 1	400	34	1990	10	659	<8	128	1660	76	150	887000	113000
13	Repl. 2	450	33	1990	10	670	<8	139	1630	70	182	877000	123000
	Repl. 3	420	29	1930	10	782	<8	123	2020	91	158	943000	57000
	Repl. 4	450	28	2000	10	610	<8	122	1500	81	153	911000	89000
	Average	430	31	1978	10	680	--	128	1703	80	161	904500	95500
	S.D.	24	3	32	0	73	--	8	223	9	15	29366	29366
	nbs 1645	1100	38	460	745	381	294	805	180	22	1760	--	--
	nbs 1645	1100	38	450	735	363	285	791	176	21	1740	--	--
	nbs 1645	1100	36	440	703	441	309	797	195	21	1740	--	--
	nbs 1646	10200	24	510	29	942	<8	30.5	610	55	120	--	--
	nbs 1646	10400	25	510	26	1010	<8	30.9	621	56	126	--	--
	nbs 1646	10300	24	510	26	934	<8	31.1	639	56	119	--	--

TABLE 13

SEDIMENT QUALITY - BUCK CREEK SYSTEM
June 16, 1990

Station Number		SEDICP AG UG/G	SEDICP AL UG/G	SEDICP AS UG/G	SEDICP BA UG/G	SEDICP BE UG/G	SEDICP CA UG/G	SEDICP CD UG/G	SEDICP CO UG/G	SEDICP CR UG/G	SEDICP CU UG/G	SEDICP FE UG/G	SEDHG HG UG/G	SEDICP K UG/G	SEDICP MG UG/G
	Repl. 1	<2	17400	19	298	0.6	7070	<0.8	<20	41.6	23.8	35000	0.097	1000	5780
	Repl. 2	<2	16800	25	292	0.6	7070	<0.8	<20	42.8	21.2	33200	0.110	1000	5550
1	Repl. 3	<2	19500	20	330	0.6	7320	<0.8	<20	45.2	23.7	36400	0.100	1700	6110
	Repl. 4	<2	18800	<8	310	0.7	7330	<0.8	<20	45.2	23.3	34800	0.088	2000	6100
	Average	---	18125	21	308	0.6	7198	---	---	43.7	23.0	34850	0.099	1425	5885
	S.D.	---	1242	3	17	0.0	147	---	---	1.8	1.2	1310	0.009	506	271
	Repl. 1	<2	14600	31	210	0.6	7730	<0.8	<20	39.6	43.9	36100	0.062	1000	5170
3	Repl. 2	<2	15700	25	214	0.6	7650	<0.8	<20	38.3	41.6	35800	0.058	2000	5310
	Repl. 3	<2	12100	19	165	0.5	6960	<0.8	<20	37.2	30.0	34000	0.040	1000	4670
	Repl. 4	<2	12600	19	177	0.4	7100	<0.8	<20	38.5	34.8	36000	0.045	1000	4790
	Average	---	13750	24	192	0.5	7360	---	---	38.4	37.6	35475	0.051	1250	4985
	S.D.	---	1690	6	24	0.1	387	---	---	1.0	6.4	991	0.010	500	304
7	grab	<2	28700	53	507	1.0	8880	<0.8	<20	36.4	107	66300	0.247	2700	6730
8	grab	<2	30400	57	538	1.0	8920	<0.8	<20	38.2	107	68800	0.254	2900	6970
10	grab	<2	34100	38	591	1.0	8900	<0.8	<20	38.3	111	71500	0.280	3500	7170
11	grab	<2	34700	33	551	1.0	8870	<0.8	<20	39.6	111	71700	0.274	3600	7300
12	grab	<2	28500	71	705	1.0	8210	<0.8	<20	33.9	108	80200	0.241	2600	6360
	Average	---	31280	50	578	1.0	8756	---	---	37.3	109	71700	0.259	3060	6906
	S.D.	---	2950	15	77	0	306	---	---	2.2	2	5241	0.017	462	374
	Repl. 1	<2	16600	<8	236	0.4	9280	<0.8	<20	42.4	38.7	22200	0.066	1000	5720
13	Repl. 2	<2	16000	<8	217	0.5	9400	<0.8	<20	47.5	38.9	25500	0.060	1000	6540
	Repl. 3	<2	14800	<8	217	0.3	8960	<0.8	<20	44.8	30.5	24000	0.050	1000	5990
	Repl. 4	<2	15400	<8	231	0.5	9010	<0.8	<20	45.6	34.1	26600	0.048	1000	6410
	Average	---	15700	---	225	0.4	9163	---	---	45.1	35.6	24575	0.056	1000	6165
	S.D.	---	775	---	10	0.1	212	---	---	2.1	4.0	1909	0.008	0	378
nbs1646		<2	22600	10	50	1.0	4210	<0.8	<20	50.0	16.0	29400	0.066	5100	8540
nbs1646		<2	19300	<8	41	1.0	3950	<0.8	<20	45.1	15.0	28200	0.072	4400	8110
nbs1646		<2	21300	19	46	1.0	4120	<0.8	<20	49.2	15.0	29200	0.073	4900	8410

TABLE 13 (Cont.)

SEDIMENT QUALITY - BUCK CREEK SYSTEM
June 16, 1990

Station Number		SEDICP MN UG/G	SEDICP MO UG/G	SEDICP NA UG/G	SEDICP NI UG/G	SEDICP P UG/G	SEDICP PB UG/G	SEDICP SB UG/G	SEDICP SI UG/G	SEDICP SN UG/G	SEDICP SR UG/G	SEDICP TI UG/G	SEDICP V UG/G	SEDICP ZN UG/G	SFR MG/KG	SVR MG/KG
	Repl. 1	892	<2	350	28	1500	<8	<8	963	<8	95.9	1120	86	119	941000	58600
1	Repl. 2	923	<2	340	25	1400	<8	<8	991	<8	93.0	1120	82	105	948000	52400
	Repl. 3	1060	<2	410	30	1600	<8	<8	853	<8	94.5	1190	93	123	931000	69400
	Repl. 4	903	<2	360	30	1600	8	<8	883	<8	94.9	1130	91	108	944000	55500
	Average	945	---	365	28	1525	---	---	923	---	94.6	1140	88	114	941000	58975
	S.D.	78	---	31	2	96	---	---	65	---	1.2	34	5	9	7257	7397
	Repl. 1	734	<2	310	26	1800	10	<8	894	<8	109	1040	81	169	946000	53900
3	Repl. 2	654	<2	320	26	1820	<8	<8	816	<8	106	1110	84	161	951000	49400
	Repl. 3	480	<2	250	22	1890	10	<8	839	<8	87.0	1120	83	134	960000	39900
	Repl. 4	529	<2	260	23	1920	9	<8	920	<8	95.0	1110	83	147	958000	42100
	Average	599	---	285	24	1858	10	---	867	---	99.3	1095	83	153	953750	46325
	S.D.	116	---	35	2	57	1	---	48	---	10.1	37	1	15	6449	6480
7	grab	2430	2	370	36	3000	26	<8	1530	<8	175	802	95	251	846000	154000
8	grab	2490	3	610	44	3170	28	<8	1460	<8	174	861	99	282	848000	152000
10	grab	3080	<2	510	39	3530	28	<8	1420	<8	176	803	100	338	831000	169000
11	grab	2750	3	570	42	3140	24	<8	1480	<8	173	873	100	335	800000	200000
12	grab	4250	<2	360	34	3830	23	<8	1700	<8	171	691	98	292	827000	173000
	Average	3000	3	484	39	3334	26	---	1518	---	174	806	98	300	830400	169600
	S.D.	744	1	114	4	339	2	---	109	---	2	72	2	37	19295	19295
	Repl. 1	241	2	390	23	1890	<8	<8	842	<8	144	1680	48	141	860000	140000
13	Repl. 2	305	<2	420	26	2190	9	<8	847	<8	129	1890	55	153	901000	98900
	Repl. 3	305	<2	480	21	2100	<8	<8	762	<8	123	1890	54	140	903000	97000
	Repl. 4	289	<2	390	25	2130	<8	<8	910	<8	123	1970	55	162	898000	102000
	Average	285	---	420	24	2078	---	---	840	---	130	1858	53	149	890500	109475
	S.D.	30	---	42	2	130	---	---	61	---	10	124	3	10	20437	20454
Nbs1646		256	2	11300	26	540	20	<8	1140	<8	31.4	736	55	125		
Nbs1646		243	2	11100	24	520	20	<8	1200	<8	29.1	599	49	125		
Nbs1646		251	3	11300	24	530	22	<8	1170	<8	30.5	675	53	121		

The average cadmium concentration in Goosly Lake was 0.8 µg/g in 1988, 1.0 µg/g in 1989, and below the detection limit in 1990. The 1989 average is suspect since several replicates were below the detection limit. In 1988 the sediments were analysed in the graphite furnace which gave lower values.

Sediment copper concentrations decreased from an average of 116 µg/g in 1987 (Godin, 1988) to 96 µg/g in 1988 and 86 µg/g in 1989, but increased to 109 µg/g in 1990.

The mercury level in Goosly Lake sediments measured 0.387 ± 0.043 µg/g in 1988, increased to 0.614 ± 0.273 µg/g in 1989, and fell to 0.259 ± 0.017 µg/g in 1990. As for cadmium, levels rose to 1989 but sharply decreased the following year.

Average lake sediment lead levels seemed to be reduced consistently from 1987 (70.1 µg/g) to 1990 (26 µg/g). The average lead content in 1988 was 50 µg/g and in 1989, 38 µg/g.

Zinc sediment concentration showed substantial variability. In 1987 sediment samples the average was 277 µg/g while in 1988 it was 299 µg/g. In 1989 the concentration was only 160.8 µg/g, but to rose again to 300 µg/g in 1990.

4.2.2 <u>Buck Creek Sediment Collection</u>. The sediment analysis results are presented in Tables 12, 13, and 14.

The arsenic detection problem was the same for the creek samples as for lake samples. The 1988 analysis did not have a low enough detection limit and the 1989 analysis of the reference material was lower than the certified value, thus failing to detect a portion of arsenic. In 1990 the detection of arsenic showed high variability (57%) in the recovery of reference material.

Name and unit conventions, if possible. (2 pages)

TABLE 14 :

SEDIMENT QUALITY - BUCK CREEK
June 23, 1988

Station		SEDICP AG UG/G	SEDGF AG UG/G	SEDICP AL UG/G	SEDICP AS UG/G	SEDICP BA UG/G	SEDICP CA UG/G	SEDICP CD UG/G	SEDGF CD UG/G	SEDICP CO UG/G	SEDICP CR UG/G	SEDICP CU UG/G	SEDICP FE UG/G	SEDHG HG UG/G	SEDICP MG UG/G	SEDICP MN UG/G
	Repl. 1	<2	0.08	19100	<50	345	8400	<0.5	0.1	10	56.0	29	37200	0.098	7600	1810
1	Repl. 2	<2	0.07	18300	<50	322	8200	0.6	0.1	10	61.6	31	38400	0.100	7900	2140
	Repl. 3	<2	0.07	17700	<50	362	7900	<0.5	0.1	20	56.0	28	36600	0.150	7600	1640
	Repl. 4	<2	0.07	16800	<50	349	8400	<0.5	0.1	20	55.6	27	37500	0.085	7200	2230
	Average	--	0.07	17975	--	345	8225	--	0.1	15	57.3	29	37425	0.108	7575	1955
	S.D.	--	0.00	971	--	17	236	--	0.0	6	2.9	2	750	0.029	287	277
	Repl. 1	<2	0.27	20100	<50	289	6800	<0.5	0.5	10	46.2	63	42700	0.160	6500	683
3	Repl. 2	<2	0.24	19100	<50	382	6600	0.8	0.8	16	41.0	71	43600	0.223	6800	815
	Repl. 3	<2	0.31	20700	<50	333	7200	0.9	0.8	20	43.9	79	41000	0.189	6500	726
	Repl. 4	<2	0.37	18600	<50	316	6700	0.7	0.8	10	42.2	81	40700	0.180	6100	774
	Average	--	0.30	19625	--	330	6825	0.8	0.7	14	43.3	74	42000	0.188	6475	750
	S.D.	--	0.06	950	--	39	263	0.1	0.2	5	2.3	8	1383	0.026	287	57
	Repl. 1	<2	0.10	18500	<50	304	8800	0.6	0.3	10	43.0	36	32600	0.100	7600	763
13	Repl. 2	<2	0.10	17700	<50	375	7800	<0.5	0.3	9	33.4	37	33500	0.110	6600	431
	Repl. 3	<2	0.07	14500	<50	226	9000	<0.5	0.2	10	43.8	32	30800	0.060	7400	981
	Repl. 4	<2	0.09	15300	<50	217	9300	0.7	0.2	10	42.3	35	30900	0.170	7500	881
	Average	--	0.09	16500	--	281	8725	0.7	0.2	10	40.6	35	31950	0.110	7275	764
	S.D.	--	0.01	1904	--	74	650	0.1	0.0	1	4.9	2	1323	0.045	457	239
	nbs 1646	<2	0.17	24700	<50	68	4400	<0.5	0.3	7	41.7	20	26000	0.082	9100	278
	nbs 1646	<2	0.17	26100	<50	67	4400	<0.5	0.3	8	43.6	17	26400	0.083	9300	281
	nbs 1646	<2	0.19	27100	<50	73	4600	<0.5	0.3	8	44.2	17	26900	0.100	9500	279

TABLE 14 (Cont.) :

SEDIMENT QUALITY - BUCK CREEK
June 23, 1988

Station Number		SEDICP NO UG/G	SEDICP NA UG/G	SEDICP NI UG/G	SEDICP P UG/G	SEDICP PB UG/G	SEDICP SI UG/G	SEDICP SR UG/G	SEDICP SN UG/G	SEDICP TI UG/G	SEDICP V UG/G	SEDICP ZN UG/G	SFR MG/KG	SVR MG/KG	TN UG/G
	Repl. 1	<5	800	39.6	1900	20	1300	110	<8	1290	82.5	120	944000	55900	1200
1	Repl. 2	<5	1000	45.1	2000	24	1400	110	<8	1370	83.6	150	951000	48700	1100
	Repl. 3	<5	1600	40.7	1800	21	1400	110	<8	1310	81.9	140	949000	51100	1100
	Repl. 4	<5	3600	38.6	2000	16	1500	110	<8	1330	80.9	140	948000	52100	1200
	Average	--	1750	41.0	1925	20	1400	110	--	1325	82.2	138	948000	51950	1150
	S.D.	--	1279	2.9	96	3	82	0	--	34	1.1	13	2944	2995	58
	Repl. 1	<5	700	30.9	2100	26	1300	98	<8	1280	86.9	160	938000	62500	1500
3	Repl. 2	<5	1000	34.9	2100	26	1400	110	<8	1140	86.9	187	922000	77500	1900
	Repl. 3	<5	700	33.0	2100	26	1200	110	<8	1160	89.1	187	921000	78600	1900
	Repl. 4	<5	900	31.2	2000	25	1300	100	<8	1140	78.9	184	939000	61100	1600
	Average	--	825	32.5	2075	26	1300	105	--	1180	85.5	180	930000	69925	1725
	S.D.	--	150	1.8	50	1	82	6	--	67	4.5	13	9832	9410	206
	Repl. 1	<5	900	33.8	2300	24	1100	89	<8	1950	66.0	140	912000	88100	2500
13	Repl. 2	<5	600	26.8	2700	26	1200	96	<8	1630	57.9	130	861000	139000	6700
	Repl. 3	<5	900	33.6	2400	34	1100	100	<8	1990	60.8	140	937000	62600	2100
	Repl. 4	<5	500	30.5	2500	19	1100	120	<8	2040	60.8	130	922000	78500	3000
	Average	--	725	31.2	2475	26	1125	101	--	1903	61.4	135	908000	92050	3575
	S.D.	--	206	3.3	171	6	50	13	--	185	3.4	6	32975	33019	2116
	nbs 1646	<5	10000	23.8	700	27	1500	36	<8	784	32.6	130	--	--	--
	nbs 1646	<5	11000	25.2	700	26	1500	37	<8	783	35.7	130	--	--	--
	nbs 1646	<5	11000	25.3	700	29	1300	38	<8	765	35.9	130	--	--	--

Cadmium concentrations in creek sediments were lower in 1988 and 1990 samples than in 1989. All stations showed cadmium levels below or close to the detection limit. In 1989 cadmium concentration was 1.0 µg/g at Station 3 and 1.2 µg/g at Station 13 downstream of Goosly Lake. In 1987 Station 13 had cadmium levels of 1.8 µg/g (Godin, 1988).

The 1989 copper results may be low since the reference material analytical result was lower than the certified value. Values ranged from a low of 3.9 µg/g at Station 13 (1989) to 74 µg/g at Station 3 (1988). Values for creek stations in 1990 fell within this range.

Mercury concentrations were analysed in 1988, 1989, and 1990. The average value at Station 3 was substantially higher in 1989 (0.438 µg/g compared to 0.188 µg/g in 1988) but there is no statistical difference between the two due to the high variability in the 1989 results. Further investigation of the changes in mercury content in Buck Creek sediments in 1990 showed levels reduced to an average range between 0.051 and 0.099 µg/g.

The lead values did not change substantially between the three stations, however a slight reduction over the years of sampling was noticeable. The lead values ranged between <8 µg/g and 26 µg/g.

4.2.3 Goosly Lake Core Profile. A sediment core profile of the lake bottom was taken from the deepest part of the lake (Station 12) on May 23, 1988, to evaluate metal contamination through time. Three replicates were taken (Table 15). Figures 3 to 11 show average concentration versus depth for arsenic, cadmium, chromium, copper, lead, manganese, mercury, silicon, and zinc.

Contamination evaluation using sediment cores is based on the assumption that there is a negligible redistribution of metals within the sediment column and relatively uniform sedimentation rates. Kemp et al. (1976) found that the assumption is valid for many metals such as copper, nickel, lead, cadmium, chromium, and mercury, but iron and manganese migrate upward from reducing to oxidizing sites. One of the problems with the impact evaluation at Equity has been the lack of proper baseline evaluation. This approach may fill the gap by describing the pre-industrial condition and therefore establish the level of contamination from Equity Silver operations.

Name and unit conventions, if poss. (2 pages)

TABLE 15 :

SEDIMENT CORE PROFILE - STATION 12
May 23, 1988

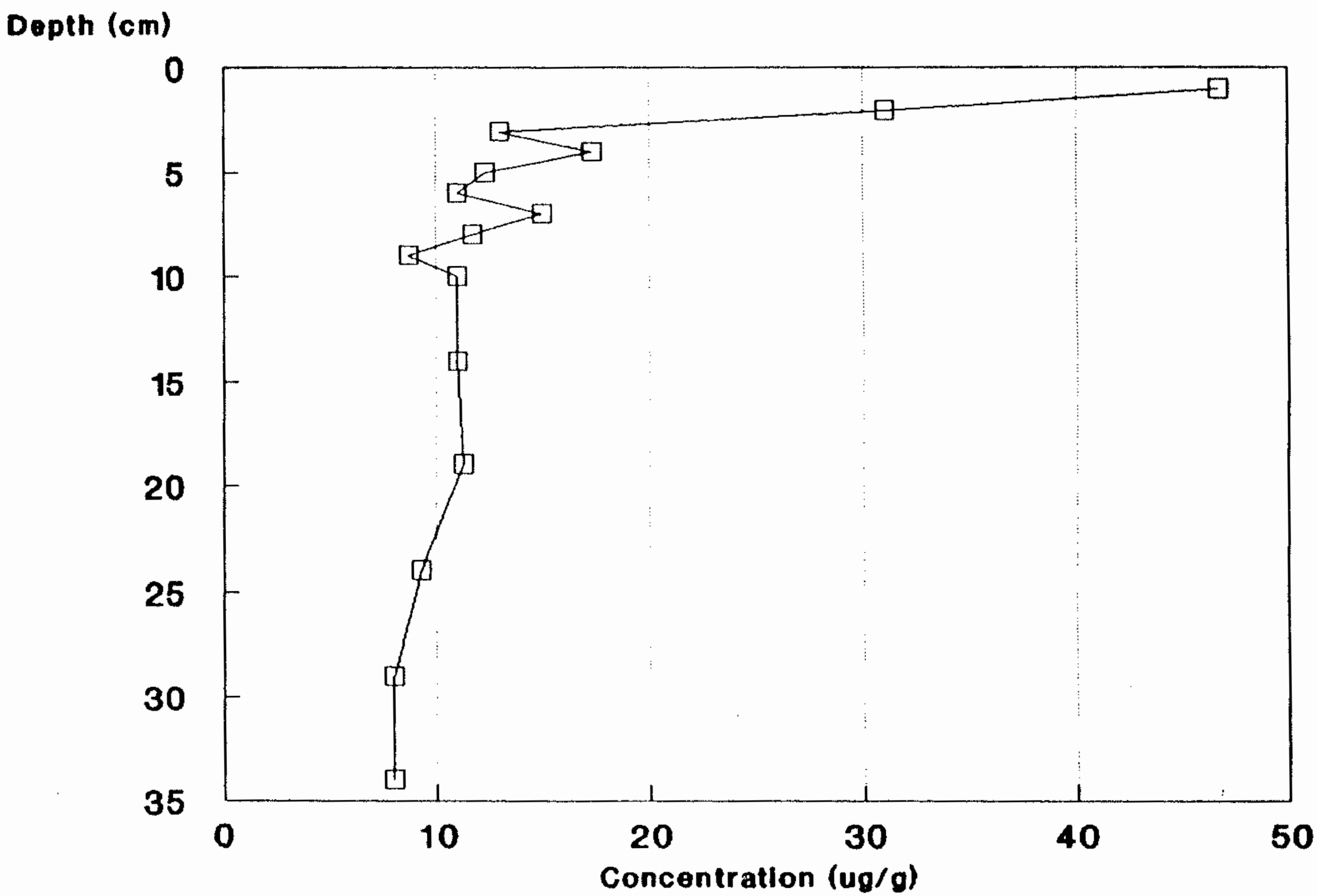
Station Number -Repl.	Core Depth CM	SEDICP AG UG/G	SEDICP AL UG/G	SEDICP AS UG/G	SEDICP CA UG/G	SEDICP CD UG/G	SEDGF CD UG/G	SEDICP CR UG/G	SEDICP CU UG/G	SEDICP FE UG/G	SEDHG HG UG/G	SEDICP MG UG/G	SEDICP MN UG/G	SEDICP MO UG/G
	1	2	36700	65	9880	2.1	1.3	38.3	130	71300	0.843	8030	3170	10
	2	<2	37200	20	9170	2.9	1.1	40.1	126	67800	0.886	8250	2720	5
	3	2	36600	20	8600	<0.8	0.99	39.6	123	65300	0.781	8310	2420	9
	4	<2	36700	23	8460	2.1	0.96	40.0	123	63500	0.636	8400	2550	5
	5	<2	37300	<8	8410	2.5	0.95	40.5	122	58600	0.466	8780	2180	4
	6	2	39600	17	8500	<0.8	0.95	41.8	123	58800	0.413	9400	2170	9
	7	<2	40800	<8	8400	2.5	0.96	42.8	123	56400	0.387	9540	1930	5
12-1	8	2	39300	10	8350	<0.8	0.81	43.2	108	54000	0.389	9060	1750	9
	9	<2	37900	<8	8430	2.3	0.87	43.1	100	53000	0.376	8440	1830	6
	10	<2	37400	<8	8170	1.9	0.90	42.9	95.3	53700	0.406	7990	1730	6
	14	<2	35500	<8	7970	2.1	0.73	42.1	97.8	48500	0.489	8570	1370	4
	19	<2	32800	<8	7200	2.0	0.76	39.6	95.4	45000	0.323	7200	1330	4
	24	<2	33000	<8	7550	2.4	0.90	39.7	136	46600	0.243	8230	1280	4
	29	<2	32000	<8	7320	2.0	1.0	39.3	142	45900	0.331	7860	1270	5
	34	<2	32500	<8	7140	2.0	0.91	39.6	100	46200	0.350	7600	1260	4
	1	<2	36300	10	9050	2.2	1.4	39.3	221	64400	0.628	8220	2700	6
	2	<2	36900	<8	8650	2.0	1.1	39.3	124	65200	0.678	8360	2600	4
	3	2	39000	10	8560	<0.8	1.1	41.0	126	62600	0.585	8900	2440	10
	4	2	36900	10	8270	<0.8	1.1	40.3	123	59500	0.423	8680	2330	9
	5	2	34700	<8	8220	<0.8	1.1	39.3	119	57200	0.380	8610	2160	10
	6	2	35900	<8	8280	2.3	1.0	40.1	109	53800	0.381	8590	1880	7
	7	<2	34800	<8	8140	2.4	1.0	40.7	95.9	51400	0.377	7780	1760	4
12-2	8	<2	35200	<8	7960	2.0	1.0	39.7	96.6	51600	0.365	7830	1730	4
	9	<2	34400	<8	7930	1.9	1.0	40.4	92.7	50600	0.530	7580	1590	3
	10	<2	34300	<8	7920	2.4	0.90	40.5	93.1	51900	0.552	7630	1630	4
	14	<2	32100	<8	7730	1.8	0.81	40.4	95.5	47100	0.419	8160	1350	4
	19	2	30500	<8	7080	2.7	0.83	38.0	95.2	44100	0.419	6990	1320	2
	24	3	33500	<8	7410	<0.8	0.86	40.2	91.2	48700	0.328	7900	1420	7
	29	2	27700	<8	7760	<0.8	0.65	37.9	79.8	43900	0.311	8210	1070	6
	34	3	32700	<8	7210	<0.8	0.76	39.7	94.6	47800	0.380	7640	1330	7
	1-2	<2	35000	65	9730	1.0	1.2	38.2	119	70100	0.744	7770	3130	2
	3	<2	38400	9	9040	<0.8	0.97	43.2	105	56300	0.549	8520	1930	4
	4	<2	38200	19	9170	1.0	1.1	42.0	124	64800	0.665	8640	2520	3
	5	2	38300	21	9090	<0.8	0.93	43.3	122	62100	0.577	8960	2360	5
	6	<2	39400	<8	9180	1.0	0.86	43.3	120	59000	0.571	9170	2110	2
	7	2	34800	29	9000	<0.8	1.1	38.2	118	65800	0.767	7910	2890	4
12-3	8	3	37400	17	9040	2.0	0.99	44.1	101	55500	0.568	8260	1840	4
	9	<2	37100	10	8900	2.0	0.95	43.2	98.0	53800	0.495	8080	1750	<2
	10	<2	35000	17	8680	1.0	1.1	42.6	96.3	55400	0.503	7900	1750	3
	14	2	33100	17	8430	0.9	0.85	41.9	98.0	49400	0.495	8500	1360	3
	19	<2	30800	18	7550	0.9	0.83	39.8	93.9	46700	0.615	7040	1350	<2
	24	2	32200	10	7900	1.0	0.82	41.5	91.6	49800	0.467	7910	1410	2
	nbs 1646	<2	21600	<8	4610	<0.8	0.34	47.3	16.8	29100	0.069	9210	275	3
	nbs 1646	<2	22300	<8	4650	<0.8	0.33	47.3	17	29200	0.077	9250	276	2
	nbs 1646	<2	23300	<8	4800	<0.8	0.34	49.4	17.8	30100	0.075	9540	285	2

TABLE 15 (Cont.):

SEDIMENT CORE PROFILE - STATION 12
May 23, 1988

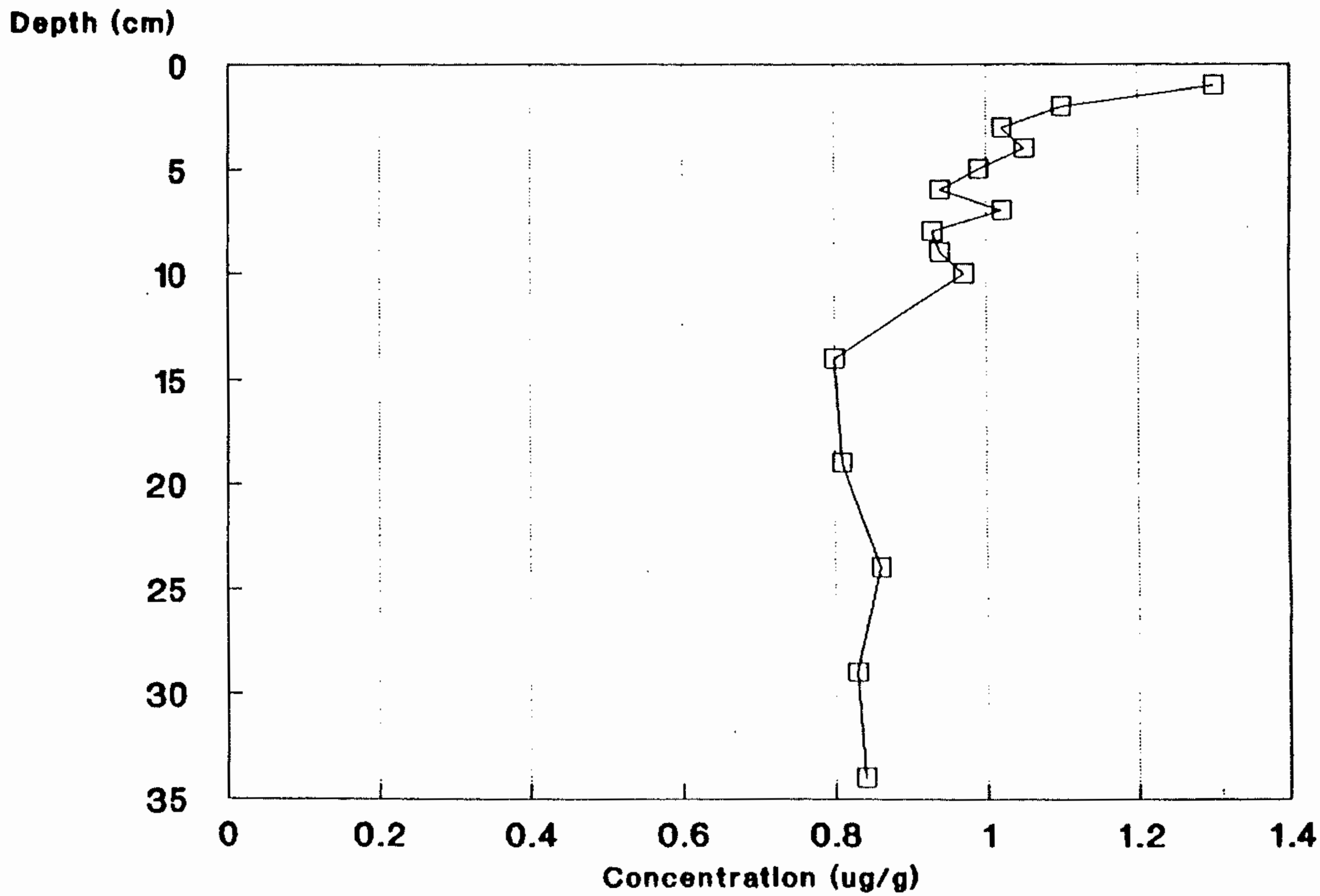
Station Number -Repl.	Core Depth CM	SEDICP NA UG/G	SEDICP NI UG/G	SEDICP P UG/G	SEDICP PB UG/G	SEDICP SI UG/G	SEDICP SN UG/G	SEDICP SR UG/G	SEDICP TI UG/G	SEDICP V UG/G	SEDICP ZN UG/G
	1	500	31	3660	18	1040	<8	175	788	120	1290
	2	470	31	2940	21	1080	<8	159	824	120	1210
	3	450	33	2490	20	1090	<8	141	785	120	1300
	4	400	31	2870	19	847	<8	140	758	110	742
	5	410	32	2360	20	632	<8	138	721	110	591
	6	440	36	2540	10	791	<8	137	785	120	517
	7	440	33	2210	10	661	<8	135	824	120	483
12-1	8	400	37	1950	<8	823	<8	131	856	120	589
	9	380	36	2000	<8	733	<8	131	838	120	440
	10	420	33	2050	<8	956	<8	126	914	120	626
	14	430	34	1800	<8	1020	<8	123	950	120	132
	19	380	30	1880	<8	1040	<8	108	927	110	344
	24	400	31	1970	<8	1170	<8	111	956	110	139
	29	430	30	1930	10	1140	<8	106	893	110	145
	34	360	31	1830	<8	1120	<8	108	893	110	129
	1	490	32	2520	23	988	<8	153	789	110	203
	2	420	30	2370	10	954	<8	147	789	110	1090
	3	450	31	2410	16	1140	<8	144	829	120	926
	4	470	35	2490	20	801	<8	138	729	110	690
	5	360	31	2430	20	771	<8	132	620	110	544
	6	380	32	1970	8	770	<8	131	724	110	405
	7	350	33	1930	<8	1240	<8	125	816	120	467
12-2	8	360	31	1900	<8	1300	<8	125	786	110	442
	9	360	27	1690	<8	740	<8	120	778	110	534
	10	380	30	1870	<8	915	<8	119	829	110	439
	14	420	35	1850	<8	959	20	116	840	110	459
	19	340	30	1830	<8	932	<8	106	848	110	245
	24	360	35	2110	<8	975	<8	109	919	110	430
	29	420	30	1850	<8	1130	<8	107	1110	110	249
	34	370	32	1940	<8	1260	<8	107	878	110	210
	1-2	500	29	3590	22	1270	<8	162	741	120	1030
	3	410	34	2070	10	1220	<8	135	890	130	572
	4	510	35	2520	25	1090	<8	141	840	130	1010
	5	520	36	2550	22	722	<8	142	755	120	701
	6	440	37	2190	17	884	<8	141	830	130	555
	7	460	31	2950	21	1270	<8	143	749	120	1120
12-3	8	420	36	2050	10	1290	<8	130	900	130	702
	9	400	35	1860	<8	1330	<8	130	913	120	633
	10	410	35	2110	<8	1380	<8	124	864	120	616
	14	440	36	1770	<8	1330	<8	121	893	120	391
	19	370	31	1950	<8	1270	<8	107	882	120	517
	24	420	33	2070	<8	1430	<8	111	871	120	434
	nbs1646	11600	22	560	<8	992	<8	34.4	609	61	120
	nbs1646	11600	22	560	<8	962	<8	34.7	638	61	121
	nbs1646	11900	25	580	<8	1000	<8	36.0	668	64	123

FIGURE 3: GOOSLY LAKE SEDIMENT PROFILE, 1988 - ARSENIC



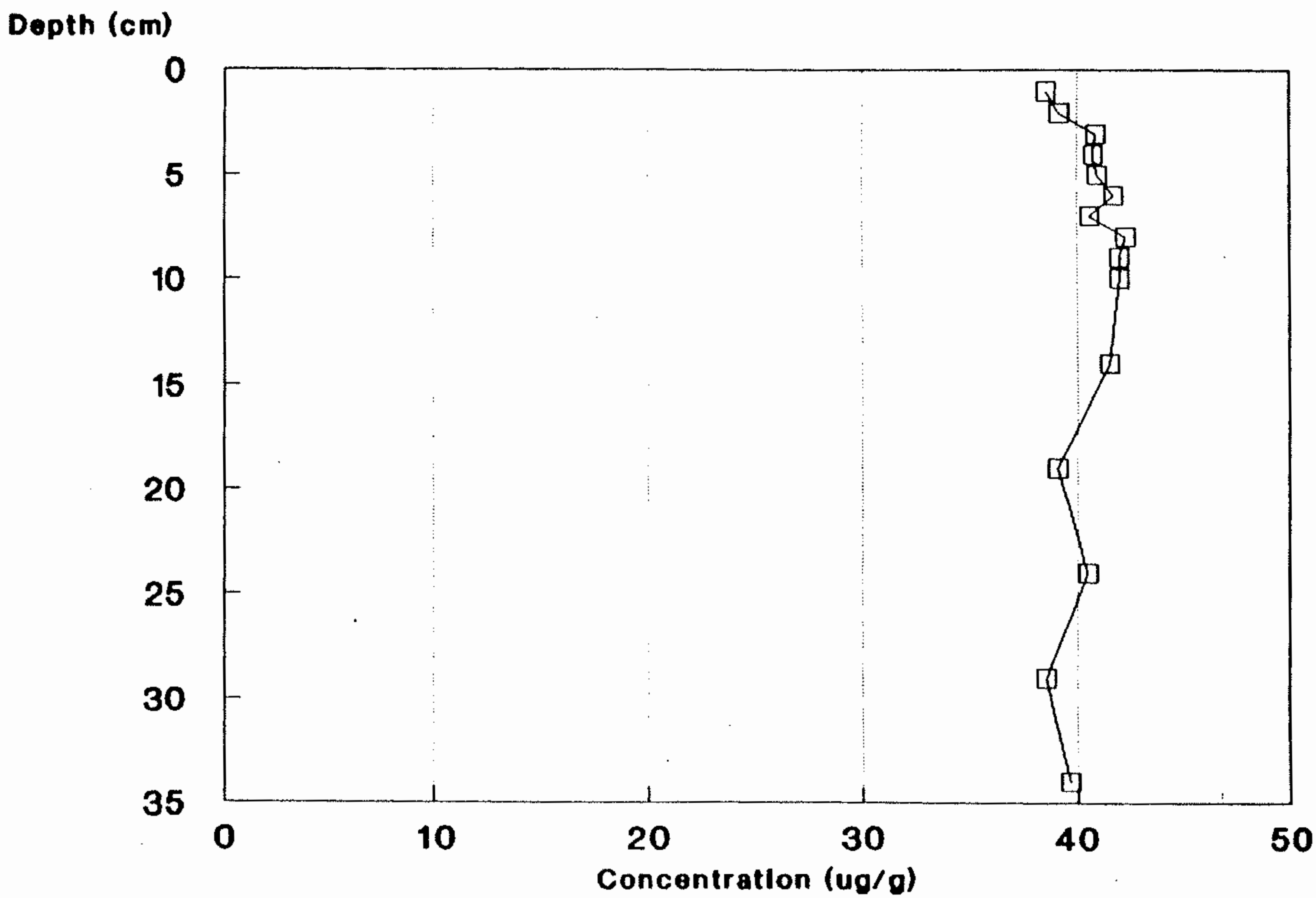
At Station 12 - May 23, 1988

FIGURE 4: GOOSLY LAKE SEDIMENT PROFILE, 1988 - CADMIUM



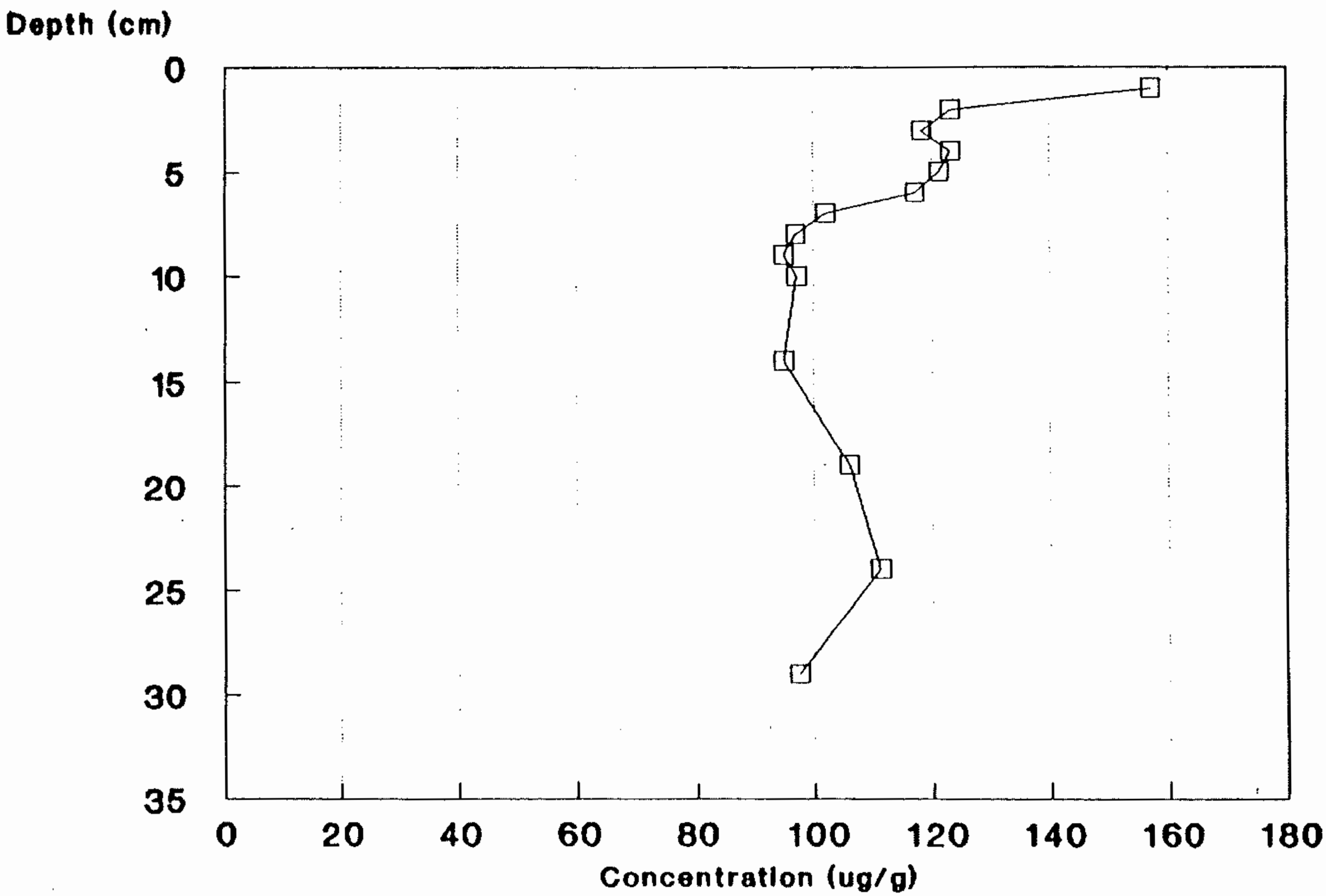
At Station 12 - May 23, 1988

FIGURE 5: GOOSLY LAKE SEDIMENT PROFILE, 1988 - CHROMIUM



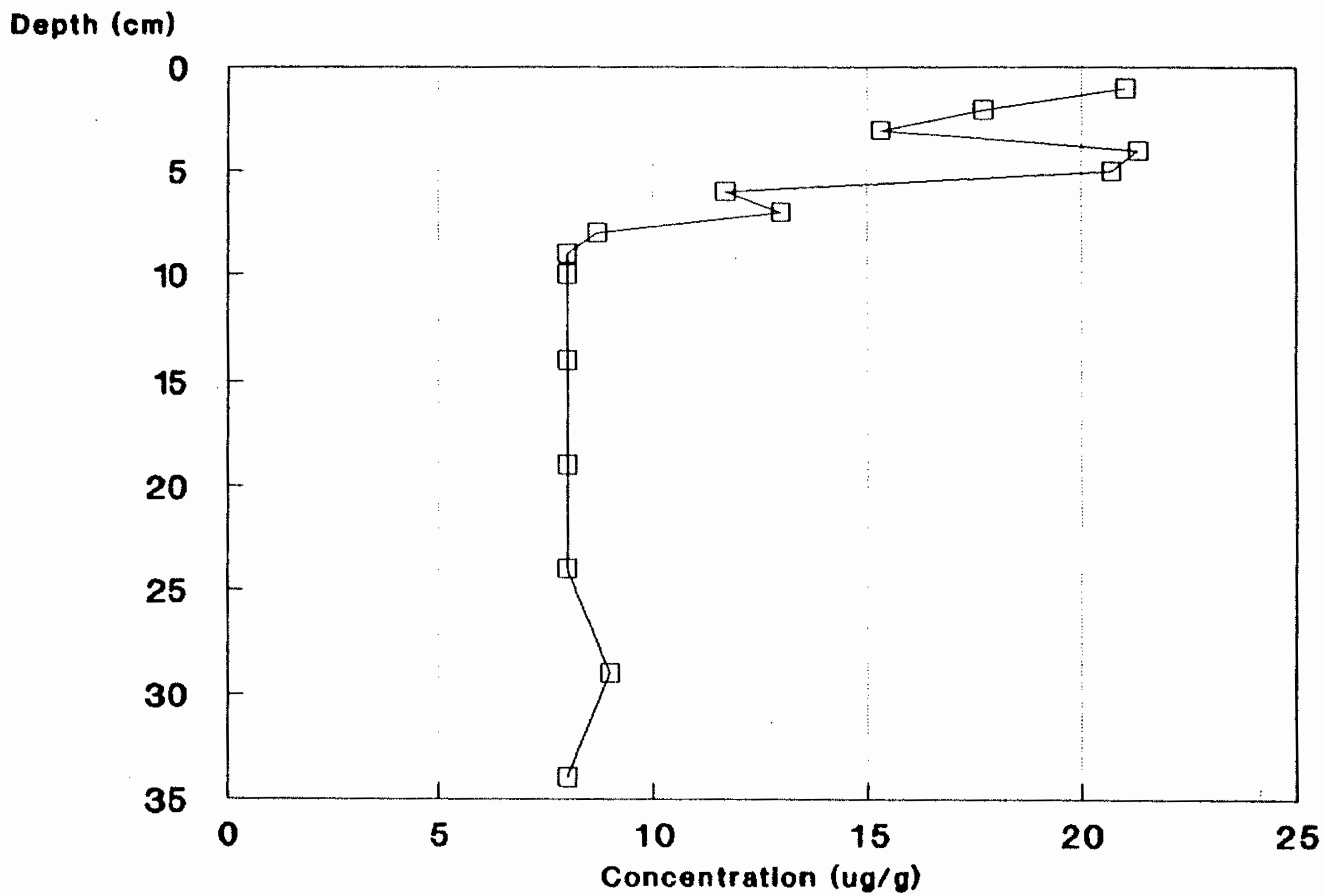
At Station 12 - May 23, 1988

FIGURE 6: GOOSLY LAKE SEDIMENT PROFILE, 1988 - COPPER



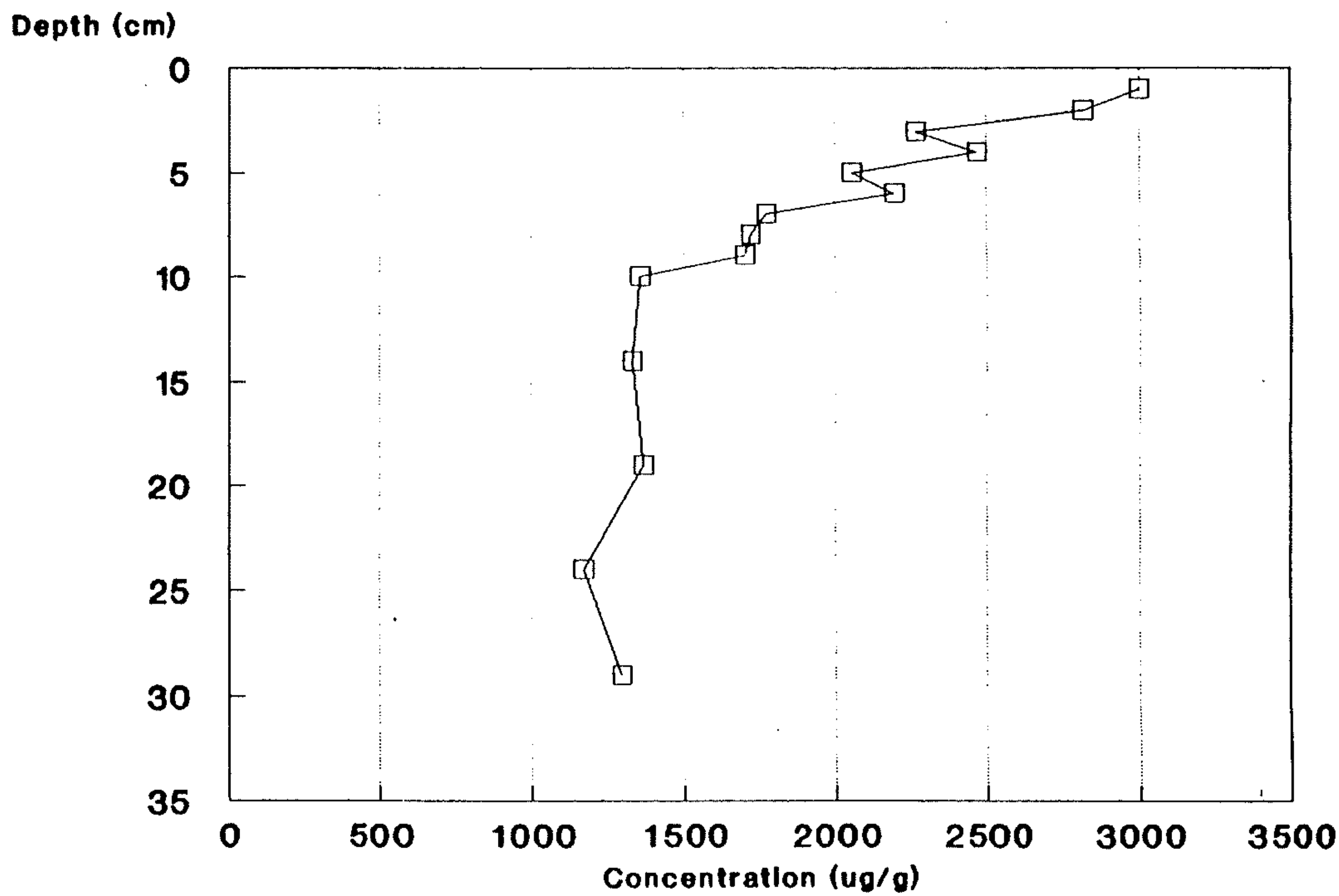
At Station 12 - May 23, 1988

FIGURE 7: GOOSLY LAKE SEDIMENT PROFILE, 1988 - LEAD



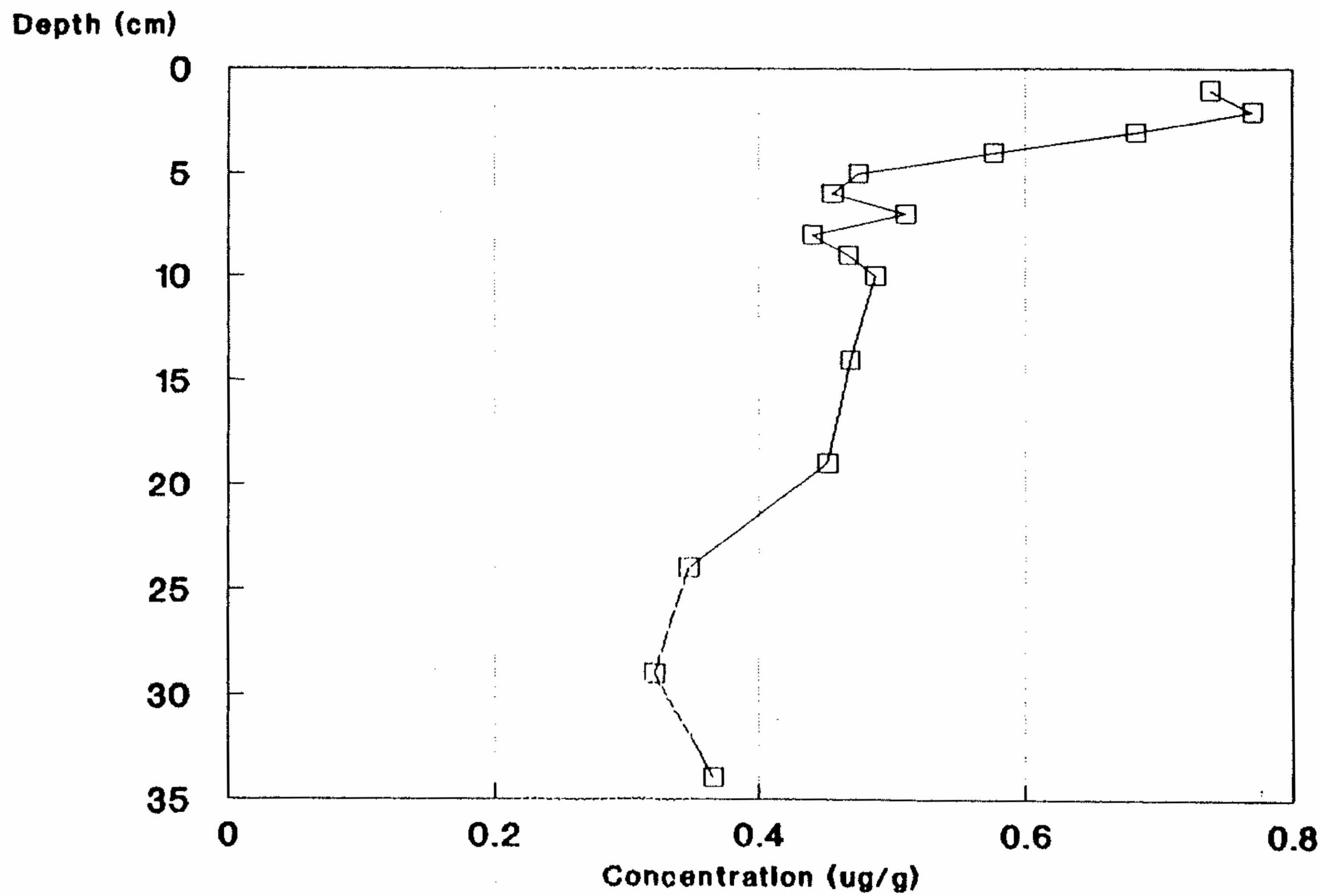
At Station 12 - May 23, 1988

FIGURE 8: GOOSLY LAKE SEDIMENT PROFILE, 1988 - MANGANESE



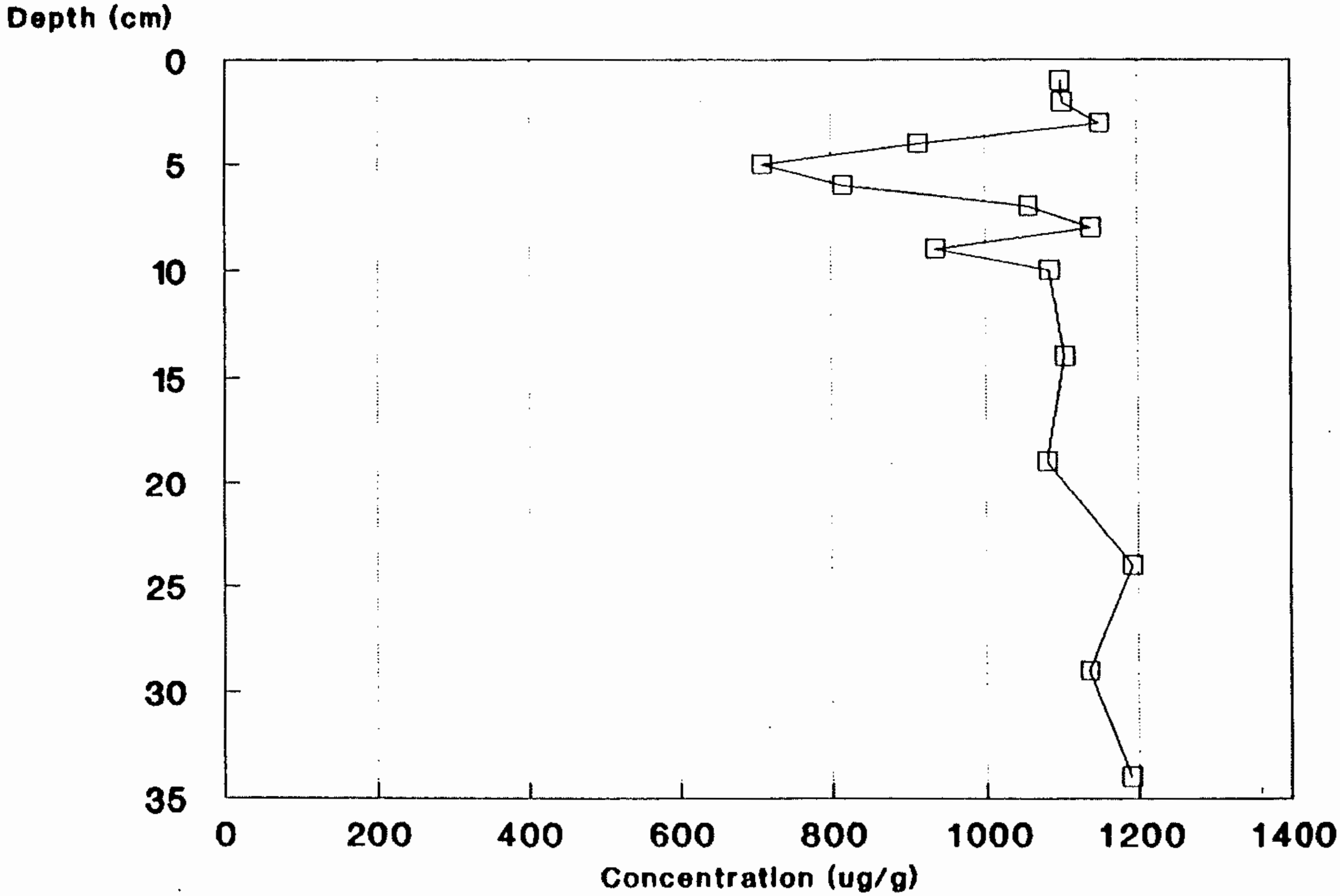
At Station 12 - May 23, 1988

FIGURE 9: GOOSLEY LAKE SEDIMENT PROFILE, 1988 - MERCURY



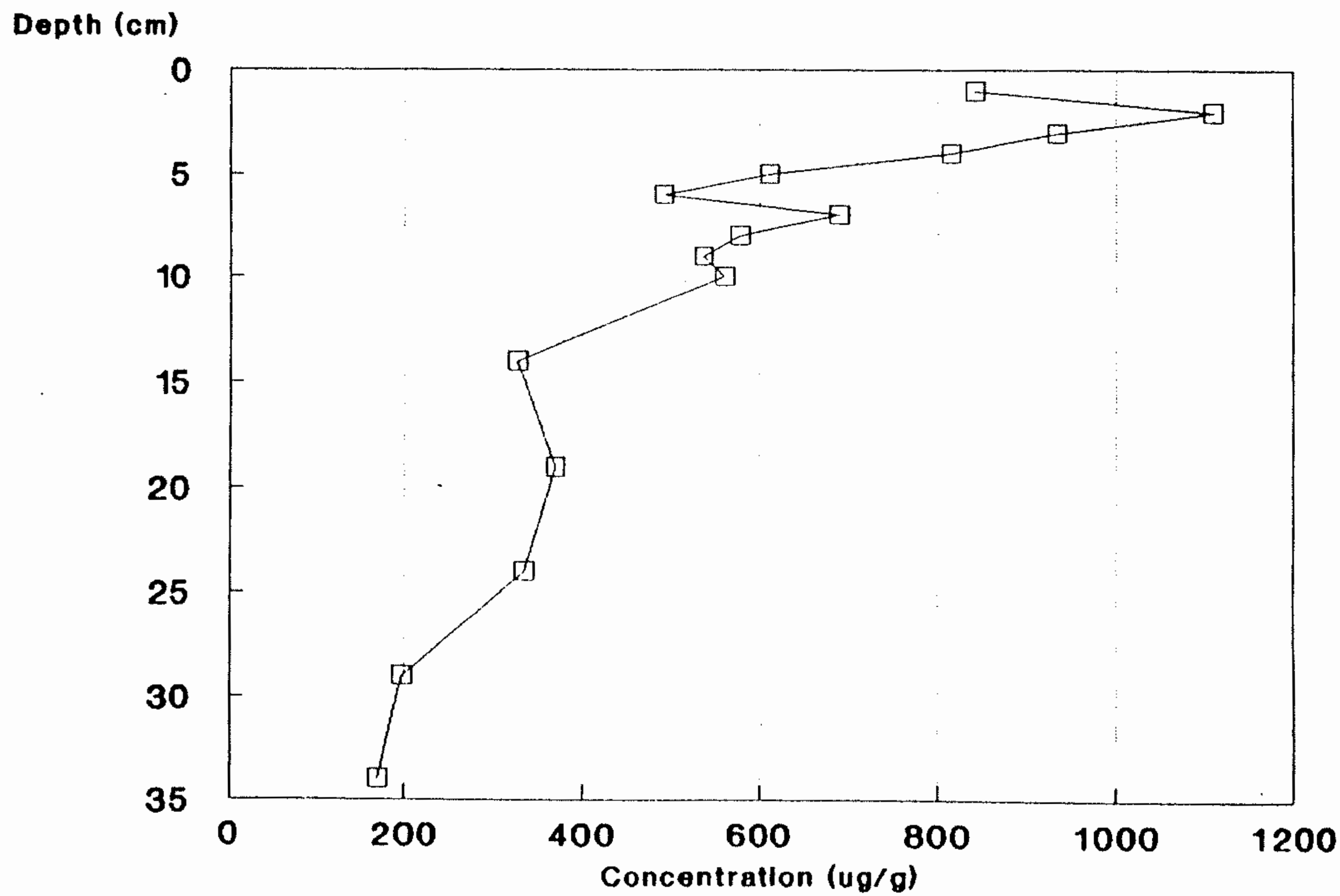
At Station 12 - May 23, 1988

FIGURE 10: GOOSLY LAKE SEDIMENT PROFILE, 1988 - SILICON



At Station 12 - May 23, 1988

FIGURE 11: GOOSLY LAKE SEDIMENT PROFILE, 1988 - ZINC



At Station 12 - May 23, 1988

Metal content increased in all profiles from 10 cm deep to the surface of the sediments. The deeper portions had a fairly constant metal concentration which could be considered the baseline concentration for this area. Johnson et al. (1986) found similar increases in recent sediments for iron, manganese, mercury, lead, zinc, and cadmium. Vertical profiles of mercury had more variability than the other metals. Nickel, copper, and chromium had little difference in Turkey Lakes profiles (Johnson et al., 1986).

The correlation of manganese to other metals in the Goosly Lake core profile was high for strontium, r=0.98; iron, r=0.96; calcium, r=0.92; cadmium, r=0.89; zinc, r=0.85; mercury, r=0.83; lead, r=0.82; copper, r=0.82; sodium, r=0.80; aluminum, r=0.76; and arsenic, r=0.74. Metals with almost no correlation or negative correlation include chromium, r=-0.05; nickel, r=-0.09; silicon, r=-0.31; and titanium, r=-0.80. From these relationships, it could be said that chromium is a conservative metal, not influenced by other metal depositions. Chromium has the near vertical metal distribution of a fairly constant deposition.

Cornwell (1986) showed that zinc profiles are less affected by manganese and iron migration in the sediment than the other trace metals. The elevated zinc concentration in the metal oxides enriched sediments would not be diagenetic feature. The strong correlation of zinc with manganese and the other metals suggests that the measurements are truly representative of the metal deposition and not of a diagenetic feature. The strong presence of iron and sulphate in the environment may suggest that sulphate reduction may prevent the migration of metals in the sediment and therefore protect the environment from degradation by the trace metals. The migration of metals to the surface along with manganese and iron has a significant effect in lakes where sedimentation rates are particularly low, as in an arctic lake.

Background concentrations were taken as the concentrations prior to the inflection point of the concentration profile. The inflection point was considered to be at the 10 cm level based on several metal analyses. This also corresponds to the beginning of the mining activity in the area based on the lead-210 determination. The baseline concentrations are discussed further in Section 4.7.

4.2.4 **Lead-210.** Results from the 1989 radiodating core are presented in Table 16 and Figures 12 and 13. Linear regression was performed on the results except that from the surface (0 cm). The equation for the line is described by the following formula:

$$y\ (^{210}Pb) = -0.01308(depth) + 0.64515$$
$$r = -0.69376$$
$$r_{(7,05)} = 0.666$$

This linear relationship is barely significant and depends on several factors as discussed below. Based on this linear relationship the surface sedimentation rate is estimated at 10.6 mm/year.

Several factors contribute to the low degree of correlation in the regression. Nevissi (1985) showed that the lead-210 deposition in the Pacific Northwest is not constant and is very much influenced by annual and seasonal variations. Assumptions of constant atmospheric lead-210 input should be re-examined in light of these new results. Contribution to this flux from radon emanations, volcanoes, forest fires, soil dust, and anthropogenic sources would all influence the lead-210 results. Joshi (1989) further explored these problems by suggesting that any lead-210 dating estimation should result from the substracting of the sedimentary radium-226 from the total lead-210 to produce unsupported lead-210. Krishnaswamy et al. (1971) showed that unsupported lead-210 results have large error values as depth increases because total lead-210 and radium-supported lead-210 activities are comparable.

TABLE 16: GOOSLY LAKE LEAD-210 ANALYSIS IN SEDIMENT CORE SAMPLE, 1988

Sediment Depth (cm)	Lead-210 Bq/g C.L.	% Moisture
5.0 - 6.0	0.82 ± 0.14	79.9
10.0 - 11.0	0.28 ± 0.11	82.1
15.0 - 16.0	0.48 ± 0.08	77.9
20.0 - 21.0	0.21 ± 0.05	79.9
25.0 - 26.0	0.33 ± 0.06	77.6
30.0 - 31.0	0.35 ± 0.07	75.4
35.0 - 36.0	0.13 ± 0.06	75.5
36.0 - 37.0	0.37 ± 0.04	76.6
37.0 - 38.0	<0.05	76.6

At Station 12 - May 23, 1988

The methodology used in our survey completely digested the samples. On the other hand, Joshi and Durham (1976) suggested that the entire sample must be brought into solution for geochronology. These same authors pointed out that lead recovery could be affected by the lag time between the radiochemical extraction and the formation of bismuth-210. At first there is a decrease due to the lead-210 activity from natural thorium, then bismuth-210 activity increased to a plateau after 10 days.

Lead had the most variable results in the 1987 sediment trap sampling program. Future investigation of dating with lead-210 should involve the analysis of radium-226, re-evaluation of the digestion procedure, the replication of the sampling to obtain a distribution of the measurement, and an evaluation of lead inputs from the mine. Cesium-137 measurements could also be used, but cesium tends to be mobile in sediment. Additionally, geochronology in sediment cores may be supported by pollen counts since logging activity in the area would result in changes to plant composition.

4.2.5 **Sequential Extraction**. It is widely accepted that adsorption of contaminants to particulate matter is a major process affecting the concentration of contaminants in the water phase. Some models view the sorption as a completely reversible process but there is growing evidence of the incomplete reversibility and slow kinetics of metals and hydrophobic contaminants. Sequential extraction was performed on the sediments in order to determine the reactivity of the sediments to biological interaction. While the chemical separation of the metal fraction does not replicate biological activity, it is believed that the gradient of chemical reactivity may reflect some of the biological sensitivity to these metals. This is one of many methodologies to attempt to evaluate desorption strength and its effect on the biota.

It is increasingly recognized that the ecological significance of pollutant inputs is determined more by the specific form and reactivity than by the accumulation rate. This effect typically refers to surface-bound pollutants, which become partly mobilized in the aquatic habitat by changes of pH and redox conditions, increased salinities, or concentration of organic chelators. The metal contaminants introduced into the aquatic environment usually represent relatively unstable chemical forms and should be more accessible for short- and middle-term geochemical processes (Förstner, 1987). A chemical leaching approach exhibits distinct advantages compared to thermodynamic models since the former incorporates information on the diagenetic effects (aging, diffusion) and reactions kinetics (Förstner, 1987); however, recent discussions of sequential extraction discourage its use due to the lack of validation of the methodology (Nirel and Morel, 1990). For example Karlsson et al. (1987) found that significant amounts of organic matter characterized as humic and fulvic acids were simultaneously incorporated in the hydrous oxide phase. The sequential extractions in this study are not utilised to identify chemical phases but to evaluate the relative ease with which the metal load is released by lowering the pH or increasing the redox potential.

The sediment extractions were performed only on sediments recently deposited in the sediment traps. Metal partitioning of anoxic sediments must be performed under oxygen free conditions, with de-aeration of leaching agents prior to contact with the samples (Förstner, 1987). The sediments subject to the sequential extraction were not collected or analysed under nitrogen atmosphere since it was felt that the sediment at the water interface would be subject to oxidation. No dissolved oxygen probe observations indicated oxygen depletion near the sediment.

The five fractions (exchangeable, carbonate, iron and manganese oxides, organic, and residual) were obtained from samples collected in 1987 and 1988 (Table 17). Elements of concern (arsenic, cadmium, copper, lead, and zinc) are represented in Figures 14 to 18.

A qualitative rather than quantitative approach is used for the evaluation of biological significance of the metal leachate from the sediment. The pH of the extractant and the oxidation state increase from the exchangeable portion to the total portion. The biological activity is interpreted according to this approach in regard to Goosly Lake sediments.

Arsenic content in the exchangeable phase was very small compared to the overall metal content. The distribution of metal through the fraction did not appear to change between stations or between the two years sampled. Cadmium content in the sediments showed a large proportion easily exchangeable. The values varied from 0.4 to 2.5 µg/g, or 50 to 69% of the total cadmium content in the sediment. Copper showed very little activity in the exchangeable and carbonate fraction. Most of the copper content was retrieved from the organic fraction which is consistent with the strong affinity of the metal with humic and fulvic acids. Lead concentrations were mostly found in the residual portion and some in the organic and sulphide fraction (listed as "organic" on Table 17).

Name and unit conventions, if possible

TABLE 17 :

SEQUENTIAL EXTRACTIONS - GOOSLY LAKE SEDIMENTS, 1987 and 1988

Station Number	TOTAL AG UG/G	EXCHAN. AG UG/G	CARBON. AG UG/G	OXIDES AG UG/G	ORGANIC AG UG/G	RESID. AG UG/G	TOTAL AL UG/G	EXCHAN. AL UG/G	CARBON. AL UG/G	OXIDES AL UG/G	ORGANIC AL UG/G	RESID. AL UG/G	TOTAL AS UG/G	EXCHAN. AS UG/G	CARBON. AS UG/G	OXIDES AS UG/G	ORGANIC AS UG/G	RESIDUAL AS UG/G
8(87)	<2	<0.4	<0.4	<0.4	0.5	<1.5	25800	3	20	751	4490	20500	74	2	<2	14	31	27
12(87)	<2	0.5	<0.4	<0.4	<0.4	<1.5	28500	3	21	738	4020	23700	87	<2	<2	15	32	40
7(88)	<2	0.6	<0.4	<0.4	0.4	<1	28200	4	22	855	4400	22900	86	<2	<2	13	29	44
11(88)	<2	<0.4	<0.4	<0.4	0.5	<1.5	30700	2	20	826	4700	25200	77	2	<2	8.6	25	41

Station Number	TOTAL CA UG/G	EXCHAN. CA UG/G	CARBON. CA UG/G	OXIDES CA UG/G	ORGANIC CA UG/G	RESID. CA UG/G	TOTAL CD UG/G	EXCHAN. CD UG/G	CARBON. CD UG/G	OXIDES CD UG/G	ORGANIC CD UG/G	RESID. CD UG/G	TOTAL CR UG/G	EXCHAN. CR UG/G	CARBON. CR UG/G	OXIDES CR UG/G	ORGANIC CR UG/G	RESIDUAL CR UG/G
8(87)	8890	4950	627	673	1830	810	<0.8	0.4	<0.2	<0.2	<0.2	<0.4	34.9	0.3	0.3	5.09	6.14	23.1
12(87)	9090	5380	707	695	1550	758	2.3	1.6	0.5	<0.2	0.2	--	36.6	0.4	0.4	4.65	5.67	25.5
7(88)	9710	5600	684	829	1740	857	3.6	2.5	0.3	<0.2	<0.2	<0.8	36.4	0.3	0.5	5.18	6.15	24.3
11(88)	10900	6590	842	899	1680	889	3.6	2.2	0.7	0.4	<0.2	<0.3	37.1	0.5	0.3	4.85	7.20	24.3

Station Number	TOTAL CU UG/G	EXCHAN. CU UG/G	CARBON. CU UG/G	OXIDES CU UG/G	ORGANIC CU UG/G	RESID. CU UG/G	TOTAL FE UG/G	EXCHAN. FE UG/G	CARBON. FE UG/G	OXIDES FE UG/G	ORGANIC FE UG/G	RESID. FE UG/G	TOTAL MN UG/G	EXCHAN. MN UG/G	CARBON. MN UG/G	OXIDES MN UG/G	ORGANIC MN UG/G	RESIDUAL MN UG/G
8(87)	72.7	<0.2	1.8	3.6	46.5	20.8	74100	<2	350	26800	13400	33600	4720	1280	493	1930	270	747
12(87)	81.5	<0.2	2.1	3.1	47.9	28.4	76700	<2	474	24100	16600	35500	4200	1900	486	1130	228	456
7(88)	88.1	<0.2	1.9	3.4	53.9	28.9	76900	<2	281	25100	16300	35200	4890	1280	468	2090	326	726
11(88)	80.0	<0.2	1.4	1.3	50.5	26.8	75700	2	134	19800	16900	38900	5270	1220	502	2220	518	810

Station Number	TOTAL PB UG/G	EXCHAN. PB UG/G	CARBON. PB UG/G	OXIDES PB UG/G	ORGANIC PB UG/G	RESID. PB UG/G	TOTAL ZN UG/G	EXCHAN. ZN UG/G	CARBON. ZN UG/G	OXIDES ZN UG/G	ORGANIC ZN UG/G	RESIDUAL ZN UG/G
8(87)	29	<2	<2	<2	9.3	<20	193	13.2	12.1	56.3	22.0	89.4
12(87)	33	<2	<2	<2	8.6	<25	225	17.6	16.3	64.4	25.8	101
7(88)	33	<2	<2	2	15	<16	257	22.9	20.1	84.9	28.1	101
11(88)	32	<2	<2	<2	12	<20	220	10.5	15.8	66.3	27.1	100

Station number (year of collection)

The levels in the exchangeable, carbonate, and oxides fractions were all below the detection limit of 2 µg/g. Zinc levels in the exchangeable and carbonate fractions were quite low. Most of the zinc content was found in the residual fraction.

The sequential extraction showed that the only metal of concern in Goosly Lake was cadmium due to the ease at which the metal may be released from the sediment.

Several experiments addressed the leachability of cadmium under various conditions. An experiment by Lion et al. (1982) with lead and cadmium using samples from oxidized surface layers of mudflats in San Francisco Bay estuary showed releases of adsorbed cadmium within a timeframe of 96 hours, whereas lead was substantially non-desorbable over the 264 hour duration of the experiment.

Salomons (1980) showed typical effects of temporal increases in sorption intensity for cadmium and zinc on fine grained fluviate particles (Table 18).

TABLE 18: PERCENT NON-DESORBABLE CADMIUM AND ZINC ON RIVER SUSPENDED MATTER AFTER TREATMENT WITH NaCl SOLUTION OF SEAWATER CONCENTRATION

Days	1	3	8	24	60
Cadmium (%)	24	30	33	37	40
Zinc (%)	60	67	70	74	88

An experiment designed by Ahlf et al. (1984), integrating sediment bioassay and the sediment extraction, showed that uptake of nickel and cadmium by algae had a significant correlation to the adsorbed/exchangeable phase as determined from the extraction studies. These extractions were based on the Tessier et al. (1979) procedure.

Bioavailability testing using a multichamber device by Calmano et al. (1988) indicated that copper and cadmium were mainly influenced by organic substances at the binding sites and these were of particular importance in the transfer of these elements into biological systems. Even at a relatively small percentage of organic substances, these materials may be involved in metabolic processes and, thus, may constitute the major carriers by which metals are transferred within the food chain.

The control of heavy metals from the mine's acid leachate, especially copper, has been through lime precipitation and settling in a sedimentation pond prior to discharge. This practice has had an effect which could be noticed in the lake (Table 19). The annual average total calcium and sulphate concentrations increased in Goosly Lake from 1982 to 1988; in 1989 these concentrations appeared to decrease. In 1990, water quality analyses indicated a net increase in concentration of these elements. This was due to the large amount of treated AMD discharge to Goosly Lake in 1990 (see Section 4.8).

4.3 Copper Complexing Capacity

Goosly Lake and Buck Creek waters are characterized by high dissolved organic content. Humic and fulvic acid are long organic molecules resulting from the decomposition of plant material and give water a tea colouration which is typical of Goosly Lake. These organic materials posess high affinity to heavy metals, and to copper, in particular. The chelation of copper tends to keep the metal in the water column; however, the binding of the metal to the organic substance reduces the toxicity of copper. A copper complexing capacity test of Buck Creek waters performed in 1989 indicated that 28.6 to 47.9 ppb of copper could potentially be bound to the organic substance (Table 20). Although the water concentration of copper in this system was above the CCREM guidelines, the risk of these levels should not result in degradation of the aquatic resources.

TABLE 19: ANNUAL AVERAGE CALCIUM AND SULPHATE CONCENTRATIONS IN GOOSLY LAKE

Year	Depth	Calcium (mg/L)	Sulphate (mg/L)
1982	Surface	12.1	15.2
	Bottom	12.2	15.4
1983	Surface	11.2	14.2
	Bottom	13.2	14.2
1984	Surface	12.5	12.7
	Bottom	12.8	13.5
1985	Surface	15.0	20.0
	Bottom	13.9	13.7
1986	Surface	16.1	29.3
	Bottom	15.3	23.2
1987	Surface	22.6	43.3
	Bottom	20.6	36.7
1988	Surface	23.1	31.5
	Bottom	24.3	33.2
1989	Surface	20.1	37.3
	Bottom	18.1	28.8
1990	Surface	28.1	64.3
	Bottom	25.1	54.4

Based on data provided by WMB Smithers, B.C. Ministry of Environment

TABLE 20: COPPER COMPLEXING CAPACITY FOR BUCK CREEK SYSTEM - 1989

Station	pH	Cu Complexing Capacity	Complexed Cu Potential
1	7.81	6.37×10^{-7}	40.8 ppb
2	8.30	4.50×10^{-7}	28.6
3	7.65	7.54×10^{-7}	47.9

4.4 Bioassays

The sediment bioassay is another method of assessing the bioavailability of particulate-associated contaminants. Bioassays were performed on various trophic levels and with different response levels in order to scan a multitude of effects that may be present in the sediments.

Results showed that lake sediment samples collected in 1989 did not contain acutely toxic chemicals; however, they may have produced sublethal effects (Table 21). Positive responses were found with the reproduction, enzyme inhibition, and genotoxicity tests. Based on the ranking system developed by Dutka (1988), the lake sediment was as toxic as the sediment collected in the siltcheck, resulting from the neutralization of acid mine drainage (Table 21). The most interesting aspect of these results is the strong inhibition of Ceriodaphnia dubia reproduction. Ceriodaphnia was not identified in the zooplankton samples collected in 1985 (Wilkes and Maclean, 1987). This could mean either that the organism was never found in the lake or had been eliminated by competition with other zooplankton populations such as Daphnia sp.

One of the arguments against the use of sediment bioassays is that the extraction does not represent the conditions in the natural system. The tests used in this series of experiments are more disturbing to the natural processes than other tests using insects such as Chironomus tentans or Hyalella sp.

Sediment was collected from Stations 8, 11, and 12 in 1990 for a Chironomus tentans 25-day emergence test. The results showed that Goosly Lake sediments were not toxic at that time since larval emergence was not affected.

4.5 Benthic Invertebrates

Benthic invertebrates were collected on July 2, 1989, and June 16-18, 1990, with an Eckman dredge (Tables 22 and 23). The samples were collected at depths varying between 13.5 and 19 metres.

If possible, move cols 2 – 7 further right to avoid crowding.

TABLE 21: SEDIMENT BIOASSAYS RESULTS – GOOSLY LAKE – 1988

Sample	*Daphnia magna* (EC50)	Microtox (EC50)	*Spirillum volutans* (behavior)	Spotplate test (EC50)	ATP-Tox System (Enzyme inhibition)	*Ceriodaphnia dubia* (Reproduction)
Lake (St.8)	Negative	Negative	Negative	Negative	Negative	50% to 1%
Siltcheck Dam (St.2)	Negative	Negative	Negative	Negative	7.3%	75% to 10%

Sample	Mutatox (Geno-toxicity)	Toxi-Chromotest (Enzyme inhibition)	Algal ATP	Rank
Lake (St.8)	18.5X Control	23%	Negative	16
Siltcheck Dam (St.2)	6.9X Control	42%	Negative	13

lc the "x" / uc the "C". Makes it easier to understand

TABLE 22: SUMMARY OF BENTHIC MACROINVERTEBRATES - GOOSLY LAKE - 1989

Species	Station 4	8	9	10	12
COPEPODA					
Harpacticoida	-	6	-	-	-
HYDRACARINA	-	1	4	-	-
DIPTERA					
Ceratopogonidae:					
Palpomyia sp.	-	1	-	-	-
Chironimidae:					
Phaenospectra sp.	21	11	2	1	29
Chironomus sp.	4	4	9	5	16
Procladius sp.	1	2	-	-	1
Rheotanytarsus sp.	-	2	3	-	1
Paratanytarsus	-	-	1	-	-
Psectrocladius sp.	-	-	1	-	-
Eukieferiella sp.	-	-	2	-	-
Cardioocladius sp.	-	-	2	-	-
Thienemanniella sp.	-	-	2	-	-
OLIGOCHAETA					
Tubificidae, juv.	16	16	2	3	14
Lumbrificidae, juv.	2	-	-	-	1
Naididae:					
Nais sp.	-	-	13	-	-
Chaetogaster sp.	-	-	5	-	-
Stylaria lacustris	-	-	2	-	-
NEMATODA	2	19	14	-	1
OSTRACODA	-	-	1	-	-
TOTAL NUMBER	46	61	61	9	63
DENSITY (#/m^2)	2044	2711	2711	400	2800
NUMBER OF TAXA	6	9	15	3	7
DIVERSITY INDEX	0.56	0.78	1.02	0.4	0.57
EVENNESS	0.72	0.82	0.87	0.84	0.67
RICHNESS INDEX	1.31	1.95	1.77	0.91	1.45

TABLE 23: BENTHIC INVERTEBRATES - GOOSLY LAKE - June 16-18, 1990

	Station 8	Station 11	Station 12
	(average of 3 replicates)		
PLANKTONIC ORGANISMS:			
Diptera			
Chaoborus sp. L	5	23	14
Calanoida			
Diaptomidae juv.	<1	1	0
Cladocera			
Daphnia rosea	4	7	<1
Daphnia schodleri	<1	0	0
(Ceriodaphnia sp?) dam.	<1	<1	0
EPIBENTHIC ORGANISMS:			
Cyclopoida			
Cyclopoida juv.	<1	<1	<1
BENTHIC ORGANISMS:			
Empididae pupae			
Chironmidae pupae			
Chironomus sp.	4	7	4
Phaenopsectra sp.	1	4	3
Oligochaeta			
Tubificidae, juv.	3	6	1
TOTAL AVERAGE NUMBER	23	47	20
DENSITY ($\#/m^2$)	1035	2102	875
NUMBER OF TAXA	6	8	9
DIVERSITY	0.47	0.65	0.76
EVENNESS	0.60	0.72	0.80
RICHNESS	1.59	1.82	2.68

TABLE 24: PERCENTAGE SIMILARITY INDEX OF BENTHIC INVERTEBRATES IN GOOSLY LAKE - 1989 AND 1990

1989	Station	8	9	10	12
	4	56.55	18.4	53.45	81.4
	8		38.7	43.15	64.85
	9			19.75	22.95
	10				58.70

1990	Station	11	12
	8	73.76	56.48
	11	77.53	

Substantial differences in the composition and community structure existed between the two surveys (Table 24). The initial structure of the benthic invertebrates in Goosly Lake was not characterized. Natural variability due to many complex biotic and abiotic factors prevented the differentiation between pollution impacts and normal change. Boyle et al. (1990) showed that the sensitivity, stability, and consistency of community indices are all dependent on initial conditions. Furthermore, they caution the biologist that the present stage of technical development may give misleading biological interpretations of the data they tend to summarize. Rather than performing more complex statitical approaches such as ordination techniques on a very small data set, the data reported here should be used qualitatively.

4.6 Zooplankton

Zooplankton data can be found in Table 25. The density of organisms varied from 40,807 to 55,010 per cubic metre.

Pennak (1978) stated that the density of rotifers in most plankton samples varies from 40,000 to 500,000 individuals per cubic metre. In our study the density varied from 17,000 to 23,000/m^3 and appeared to be governed by food availability. The most abundant and common rotifers in general open-water plankton communities are Keratella sp., Kellicottia sp., Filina sp., and Asplanchna sp.; these species are found in Goosly Lake (Table 25). Pennak mentioned that alkaline waters generally contain relatively few species but large numbers whereas acid waters contain large numbers of species and few individuals. In seven earlier surveys, Wilkes and Maclean (1987) found two fewer species but a higher density than this survey. The predator Asplanchna sp. was found in much greater numbers than previous surveys, but Polyartha sp., found in previous late summer surveys, was not found.

Copepoda are represented by the two suborders Calanoida and Cyclopoida. Generally the cyclopoids are represented by only one dominant species, and often codominance with a clanoid is encountered. Pennak stated that Cyclops biscuspidatus is generally one of the dominant species. This species was identified in Wilkes' surveys but our survey only identified Cyclops scutifer. It was not possible to determine if the species was well identified or reflected a change in lake conditions (anthropogenic or seasonal). Cyclops scutifer is said to be abundant in the hypolimnion of limnetic habitats.

TABLE 25: ZOOPLANKTON - GOOSLY LAKE - June 16-18, 1990

	Station 8	Station 11	Station 12
	(average of 3 replicates, in organisms/m^3)		
Diptera			
Chaoborus sp. L	4	2	3
Chaoborus sp. P	<1	0	0
Calanoida			
Aglaodiaptomus leptopus	0	34	0
Diaptomidae juv.	3	71	0
Epischura sp juv.	0	0	2
Calanoida juv.	5	0	8
Nauplii	13109	15577	14570
Cyclopoida			
Cyclops scutifer	1017	1090	934
Cyclopoida juv.	4916	14336	6668
Cladocera			
Daphnia (pulex?)	0	2	0
Daphnia rosea	1153	2524	1037
Daphnia schodleri	49	49	160
Daphnia ambigua	48	54	46
Ceriodaphnia sp.	5	0	0
Bosmina longirostris	312	443	200
Sida crystalina	5	0	3
Leptodora kindtii	2	0	0
Rotifera			
Asplancha sp?	4112	3957	4660
Kellicotia sp.	17154	16024	11340
Filina sp.	1745	703	1000
Keratella (quadradenta)	117	144	117
Keratella (cochlearis)	59	0	58

The Diaptomidae family in the calanoids suborder have a preference for cold waters. It is interesting to note that species from this family were mostly found at Station 11, where the hypolimnion was colder for a greater depth of the water column. More calanoid species were identified in this survey (4) than in Wilkes' seven surveys (1).

The 1990 survey showed a high proportion of both calanoid and cyclopoid juveniles as compared to adults (18x to 25x). This is a good indication that reproduction was not affected.

Cladoceran populations are known to exhibit large fluctuations in numbers, starting with low numbers in early spring and increasing to large populations as the temperature reaches 6 to 12°C. Summer populations are usually smaller. Caldoceran species in the same lake have frequently shown large fluctuations from year to year. Sida crystalina has shown population maxima during fall in Goosly Lake, which could explain the low numbers in July. Daphnia sp., Bosmina sp., and Ceriodaphnia sp. are common limnetic species. Cladocerans are well known for their sensitivity to toxic substances and especially their sensitivity to metals. The population seemed to be adequately diverse in the lake with large numbers of individuals. This seems to indicate good lake conditions with respect to metal concentrations.

4.7 Fish Tissue Analysis

The muscle tissue metal analysis for mercury content in rainbow trout showed that the levels were well below the comsumption limit of 0.5 µg/g wet weight (Table 26); however, one peamouth chub accumulated higher concentrations. The reason for this difference is not clear but it may be related to the diet. All stomach contents evaluated showed that the chub were feeding exclusively on zooplankton while the trout were feeding on insect larvae and adults.

The lipid content did not reveal much about the fitness of the fish due to the high variability in the results (Table 27). No relationship could be found for lipid content and age or species. The lipid content would be affected seriously by reproduction stage; trout were collected after spawning and, therefore, would be expected to have lower lipid content in their tissues.

All tissue metal concentrations were reported on a dry weight basis (Tables 28 to 31). The muscle tissue from rainbow trout collected in Goosly Lake by B. Wilkes compared relatively well with our results. Tissue differences between rainbow trout and peamouth chub were more evident. Metal content in peamouth tissues was higher in almost all instances for muscle, gills, and kidney. The most striking difference between the two species were for the kidney levels where cadmium, mercury, and zinc concentrations were much higher in the chub population.

TABLE 26: FISH MUSCLE MERCURY ANALYSIS - GOOSLY LAKE - June 17, 1990

Rainbow trout

Sample #	Age (year)	Weight (gm)	Length (cm)	Mercury content (µg/g wet weight)
1	4	53.2	17.6	0.087
2	4	59.8	17.0	0.081
3	4	79.9	20.2	0.134
4	4	64.9	18.0	0.088
5	4	104	20.4	0.080
6	4	77.0	19.2	0.078
7	3	43.3	16.0	0.084
8	3	57.8	17.7	0.064
9	3+	87.3	20.5	0.051
10	3+	60.1	18.0	0.069
11	3	60.0	17.7	0.072
12	3	49.2	16.5	0.071
13	3	52.4	16.6	0.060
14	2+	54.4	17.0	0.072
15	2+	47.8	17.2	0.072
16	2+	40.6	15.4	0.052
17	2+	26.7	13.7	0.056

Peamouth chub

Sample #	Age (year)	Weight (gm)	Length (cm)	Mercury content (µg/g wet weight)
1	3+	53.6	17.0	0.297
2	3+	-	17.2	0.505
3	3+	39.0	15.4	0.225
4	3+	44.3	15.7	0.207
5	3+	57.9	18.1	0.462
6	3+	42.6	14.9	0.021
7	3+	43.3	16.6	0.142
8	3+	-	16.8	0.450
9	3+	-	17.0	0.464
10	3+	48.1	15.9	0.454
11	3+	47.8	17.6	0.300

Note: Peamouth chub stomachs contained essentially zooplankton while rainbow trout stomachs contained insect larvae and numerous flying adults.

TABLE 27: LIPID CONTENT IN FISH MUSCLE - GOOSLY LAKE - June 17, 1990

Fish Number	Lipid (%)	Fish Number	Lipid (%)
Rainbow trout		Peamouth chub	
1	0.5	17	1.3
2	0.9	18	1.2
3	1.0	19	0.7
4	1.4	20	1.2
5	1.5	21	0.5
6	1.0	22	0.9
7	0.8	23	1.0
8	1.2	24	0.7
9	1.1	25	0.9
10	0.6	26	1.2
11	1.3	27	0.5
12	0.6		
13	0.6		
14	0.9		
15	1.3		
16	0.9		
17	1.2		

4.8 Ecological Risk Assessment

DRAFT

An ecological risk assessment based on the work of Håkanson (1980) was previously described for Goosly Lake (Godin, 1988). The current report attempts to better define certain parameters that were not well defined in the past assessment. The contamination factor described by Håkanson (1980) is defined in two ways: based on literature references and on the core data (Table 32). The level of contamination increases according to the literature contamination factor, while that derived from the core values decreases.

The latter may better reflect the actual discharges as there is a delay of a year or two between release and sedimentation. The mine discharges of elements through the AMD treatment system vary substantially from year to year (Table 33, company files). The contamination factor based on the sediment core data seems to follow the AMD discharge to Bessemer Creek with a lapse of two years.

use name + unit conventions, if possible (Tables 28-31)

TABLE 28 :

METAL

FISH MUSCLE ANALYSIS - GOOSLY LAKE
June 17, 1990

	Fish Number	BIOICP AL UG/G	BIOICP AS UG/G	BIOICP BA UG/G	BIOICP BE UG/G	BIOICP CA UG/G	BIOICP CD UG/G	BIOGF CD UG/G	BIOICP CO UG/G	BIOICP CR UG/G	BIOICP CU UG/G	BIOICP FE UG/G	BIOHG HG UG/G	BIOICP K UG/G	BIOICP MG UG/G	BIOICP MN UG/G
Rainbow	1	<4	<4	0.1	<0.08	1020	<0.4	0.010	<0.4	<0.4	5.4	23.2	0.419	21500	1420	0.95
trout	2	<4	<4	0.2	<0.08	960	<0.4	<0.008	<0.4	<0.4	1.7	16.9	0.403	20800	1330	1.20
	3	<4	<4	<0.08	<0.08	1100	<0.4	<0.008	<0.4	<0.4	1.2	15.4	0.583	19400	1270	0.70
	4	<4	<4	<0.08	<0.08	1080	<0.4	0.030	<0.4	<0.4	1.6	15.6	0.432	20000	1290	0.80
	5	<4	<4	<0.08	<0.08	937	<0.4	0.020	<0.4	<0.4	1.7	14.9	0.365	18100	1200	0.80
	6	<4	<4	<0.08	<0.08	863	<0.4	0.010	<0.4	<0.4	1.6	18.3	0.396	19400	1240	0.85
	7	<4	<4	<0.08	<0.08	1310	<0.4	0.009	<0.4	<0.4	2.3	22.0	0.384	22100	1510	0.80
	8	<4	<4	<0.08	<0.08	700	<0.4	<0.008	<0.4	<0.4	1.8	19.7	0.300	17500	1230	0.70
	9	<4	<4	<0.08	<0.08	938	<0.4	0.010	<0.4	<0.4	1.1	14.4	0.371	20500	1370	0.60
	10	<4	<4	<0.08	<0.08	1140	<0.4	<0.008	<0.4	<0.4	1.9	21.3	0.356	20800	1320	0.80
	11	<4	<4	<0.08	<0.08	1130	<0.4	0.009	<0.4	<0.4	1.4	15.5	0.320	18800	1270	0.80
	12	<4	<4	<0.08	<0.08	1030	<0.4	0.010	<0.4	<0.4	1.9	20.3	0.348	19600	1270	0.80
	13	<4	<4	<0.08	<0.08	944	<0.4	0.010	<0.4	<0.4	1.7	17.0	0.303	20000	1300	0.95
	14	<4	<4	0.1	<0.08	1510	<0.4	0.020	<0.4	<0.4	1.7	18.3	0.338	18400	1180	0.95
	15	<4	<4	0.4	<0.08	1310	<0.4	0.009	<0.4	<0.4	1.4	18.5	0.340	17500	1180	0.70
	16	<4	<4	0.2	<0.08	810	<0.4	<0.008	<0.4	<0.4	1.6	19.0	0.260	19200	1280	0.70
	17	<4	<4	0.2	<0.08	1310	<0.4	0.020	<0.4	<0.4	1.7	20.2	0.250	19000	1310	1.20
Peamouth	18	<4	<4	2.6	<0.08	2420	<0.4	0.010	<0.4	<0.4	2.9	29.5	1.580	18200	1310	1.50
chub	19	<4	<4	2.5	<0.08	2730	<0.4	0.120	<0.4	<0.4	2.7	35.1	2.660	15800	1150	1.30
	20	<4	<4	2.0	<0.08	2960	<0.4	0.040	<0.4	<0.4	2.8	24.8	1.100	17700	1240	1.30
	21	<4	<4	1.8	<0.08	2430	<0.4	<0.008	<0.4	<0.4	3.4	26.0	0.998	17600	1400	1.60
	22	<4	<4	2.3	<0.08	3910	<0.4	0.150	<0.4	0.8	3.0	53.6	2.470	17800	1320	2.20
	23	<4	<4	0.6	<0.08	1730	<0.4	0.010	<0.4	<0.4	1.2	10.2	0.100	17100	1320	3.10
	24	<4	<4	1.6	<0.08	2550	<0.4	0.030	<0.4	<0.4	2.0	19.5	0.730	16600	1270	1.10
	25	<4	<4	2.9	<0.08	2470	<0.4	0.070	<0.4	<0.4	2.6	40.4	2.380	16000	1120	1.40
	26	<4	<4	1.5	<0.08	2530	<0.4	0.050	<0.4	<0.4	2.5	32.1	2.470	16600	1330	1.30
	27	<4	<4	2.4	<0.08	2680	<0.4	0.094	<0.4	<0.4	2.7	39.0	2.440	17300	1190	1.50
	28	<4	<4	2.4	<0.08	2230	<0.4	0.050	<0.4	<0.4	2.8	38.7	1.580	17900	1300	1.10

31.7

TABLE 28 (Cont.)

FISH MUSCLE ANALYSIS - GOOSLY LAKE
June 17, 1990

	Fish Number	BIOICP MO UG/G	BIOICP NA UG/G	BIOICP NI UG/G	BIOICP P UG/G	BIOICP PB UG/G	BIOGF PB UG/G	BIOICP SB UG/G	BIOICP SE UG/G	BIOICP SI UG/G	BIOICP SN UG/G	BIOICP SR UG/G	BIOICP TI UG/G	BIOICP V UG/G	BIOICP ZN UG/G	H2O %
Rainbow trout	1	<0.8	1870	<2	12700	5	2.95	<4	<4	4	<4	3.3	<0.2	<0.8	33.2	79.2
	2	<0.8	1910	<2	11900	<4	0.59	<4	<4	<4	<4	3.0	<0.2	<0.8	29.8	79.8
	3	<0.8	1900	<2	11100	<4	0.52	<4	<4	<4	<4	3.1	<0.2	<0.8	24.0	77.0
	4	<0.8	1480	<2	11500	<4	0.97	<4	<4	<4	<4	3.2	<0.2	<0.8	31.1	79.7
	5	<0.8	1290	<2	10700	<4	0.33	<4	<4	<4	<4	2.9	<0.2	<0.8	23.5	78.1
	6	<0.8	2470	<2	11000	<4	0.32	<4	<4	<4	<4	2.5	<0.2	<0.8	30.7	80.2
	7	<0.8	1900	<2	13200	<4	0.93	<4	<4	7	<4	4.2	0.4	<0.8	36.0	78.0
	8	<0.8	1990	<2	10100	<4	0.21	<4	<4	5	<4	2.8	<0.2	<0.8	39.1	78.8
	9	<0.8	1870	<2	11500	<4	0.41	<4	<4	<4	<4	2.9	<0.2	<0.8	25.9	86.2
	10	<0.8	2160	<2	11800	<4	0.45	<4	<4	<4	<4	4.3	<0.2	<0.8	31.9	80.5
	11	<0.8	1870	<2	11000	<4	0.29	<4	<4	<4	<4	3.7	<0.2	<0.8	33.3	77.6
	12	<0.8	2110	<2	11800	<4	0.60	<4	<4	<4	<4	3.6	<0.2	<0.8	28.4	79.5
	13	<0.8	1430	<2	11800	<4	0.90	<4	<4	7	<4	3.0	<0.2	<0.8	30.1	80.2
	14	<0.8	2000	<2	11200	<4	0.66	<4	<4	<4	<4	5.5	<0.2	<0.8	35.8	78.7
	15	<0.8	1810	<2	10400	<4	0.18	<4	<4	<4	<4	5.2	<0.2	<0.8	35.8	78.7
	16	<0.8	1730	<2	10700	<4	0.11	<4	<4	<4	<4	2.8	<0.2	<0.8	27.0	80.2
	17	<0.8	1930	<2	11400	<4	0.21	<4	<4	5	<4	4.7	<0.2	<0.8	31.4	77.6
Peamouth chub	18	<0.8	1950	<2	11000	<4	0.38	<4	<4	<4	<4	12.3	<0.2	<0.8	76.5	81.2
	19	<0.8	2020	<2	9590	<4	0.11	<4	<4	<4	<4	12.0	<0.2	<0.8	62.8	81.0
	20	<0.8	1920	<2	10700	<4	0.21	<4	<4	<4	<4	17.4	<0.2	<0.8	70.1	79.6
	21	<0.8	2010	<2	10900	<4	0.22	<4	<4	6	<4	12.6	<0.2	<0.8	74.4	79.3
	22	<0.8	2380	<2	11100	<4	0.23	<4	<4	5	<4	16.8	<0.2	<0.8	71.2	81.3
	23	<0.8	1830	<2	9580	<4	0.15	<4	<4	5	<4	6.8	<0.2	<0.8	35.7	79.3
	24	<0.8	1650	<2	9720	<4	0.06	<4	<4	<4	<4	17.1	<0.2	<0.8	51.8	80.6
	25	<0.8	2750	<2	9730	<4	0.22	<4	<4	<4	<4	11.0	<0.2	<0.8	87.5	81.1
	26	<0.8	1610	<2	9830	<4	0.61	<4	<4	<4	<4	10.3	<0.2	<0.8	58.4	81.2
	27	<0.8	1780	<2	10200	<4	0.17	<4	<4	6	<4	12.1	<0.2	<0.8	66.3	81.4
	28	<0.8	1870	<2	10100	<4	0.27	<4	<4	5	<4	10.2	<0.2	<0.8	121	81.1

TABLE 29

FISH GILL METAL ANALYSIS - GOOSLY LAKE
June 17, 1990

	Fish Number	BIOICP AL UG/G	BIOICP AS UG/G	BIOICP BA UG/G	BIOICP BE UG/G	BIOICP CA UG/G	BIOICP CD UG/G	BIOGF CD UG/G	BIOICP CO UG/G	BIOICP CR UG/G	BIOICP CU UG/G	BIOICP FE UG/G	BIOHG HG UG/G	BIOICP K UG/G	BIOICP MG UG/G	BIOICP MN UG/G
Rainbow trout	1	20	<5	7.0	<0.09	41100	0.6	0.15	<0.5	<0.5	3.8	141	0.166	10700	1400	17.6
	2	15	<6	6.8	<0.1	38300	<0.6	0.20	<0.6	<0.6	2.0	145	0.140	8500	1260	33.6
	3	26	<4	4.9	<0.08	28800	<0.4	0.14	0.5	<0.4	1.7	144	0.277	8570	1000	14.4
	4	56	<5	6.7	<0.1	42500	<0.5	0.13	<0.5	<0.5	4.9	174	0.201	9100	1450	23.4
	5	12	<4	5.0	<0.08	33100	0.7	0.30	0.6	<0.4	1.9	116	0.211	8370	1100	16.6
	6	94	<4	7.5	<0.08	35700	0.8	0.30	1.3	<0.4	2.4	351	0.165	10100	1350	38.8
	7	27	<5	3.5	<0.1	30000	<0.5	0.20	0.6	<0.5	4.7	175	0.154	10900	1150	11.9
	8	25	<7	6.7	<0.1	41600	<0.7	0.18	<0.7	<0.7	2.0	92.3	0.130	8800	1660	13.0
	9	27	<7	7.2	<0.1	38200	<0.7	0.22	<0.7	<0.7	1.9	166	0.210	9200	1300	16.5
	10	40	<6	6.1	<0.1	51300	<0.6	0.24	0.8	<0.6	2.4	184	0.150	11000	1710	26.0
	11	23	<4	4.3	<0.08	35100	<0.4	0.16	0.6	<0.4	1.8	120	0.157	9900	1240	12.3
	12	26	<5	6.7	<0.1	36400	<0.5	0.18	0.6	<0.5	1.9	150	1.420	11100	1420	15.8
	13	16	<5	5.0	<0.1	39100	<0.5	0.18	<0.5	<0.5	2.1	152	0.132	10000	1290	19.6
	14	29	<6	4.1	<0.1	34600	0.8	0.23	0.8	0.6	2.3	142	0.124	9200	1260	19.3
	15	52	<6	6.9	<0.1	36900	0.6	0.18	0.6	<0.6	1.7	192	0.140	11300	1480	20.5
	16	Not available														
	17	14	<6	3.9	<0.1	41300	<0.6	0.25	<0.6	<0.6	1.7	134	0.123	11800	1490	14.7
Peamouth chub	18	8	<7	34.9	<0.1	57000	<0.7	0.17	<0.7	<0.7	2.5	142	0.306	10000	2810	21.2
	19	96	<5	40.5	<0.1	48200	1	0.32	1.5	<0.5	3.5	320	0.807	11000	2660	22.7
	20	10	<10	23.3	<0.2	38900	<1	0.10	<1	<1	3.1	143	0.207	11000	2260	17.0
	21	18	<8	21.0	<0.2	44800	<0.8	0.26	2	1	4.0	184	0.200	9900	2330	23.8
	22	50	<5	29.6	<0.1	52100	<0.5	0.25	0.8	<0.5	3.7	220	0.618	11700	2640	34.7
	23	26	<6	9.4	<0.1	35800	<0.6	0.08	1	<0.6	4.1	103	0.048	9000	1410	80.0
	24	70	<9	30.2	<0.2	50900	<0.9	0.10	1	<0.9	3.0	218	0.160	10000	2670	37.9
	25	14	<5	52.5	<0.1	62000	0.7	0.09	0.8	<0.5	3.0	177	0.843	11100	2820	34.0
	26	14	<5	19.6	<0.1	45000	0.8	0.16	1.1	<0.5	4.2	228	0.744	10500	2190	15.8
	27	37	<6	33.0	<0.1	44400	<0.6	0.28	1	<0.6	3.3	198	0.822	11000	2470	27.4
	28	20	<6	20.9	<0.1	40800	<0.6	0.10	0.7	<0.6	3	182	0.335	10000	2260	21.0

TABLE 29 (Cont.)

FISH GILL METAL ANALYSIS - GOOSLY LAKE
June 17, 1990

	Fish Number	BIOICP MO UG/G	BIOICP NA UG/G	BIOICP NI UG/G	BIOICP P UG/G	BIOICP PB UG/G	BIOGF PB UG/G	BIOICP SB UG/G	BIOICP SE UG/G	BIOICP SI UG/G	BIOICP SN UG/G	BIOICP SR UG/G	BIOICP TI UG/G	BIOICP V UG/G	BIOICP ZN UG/G	H2O %
Rainbow trout	1	<0.9	6540	<2	29100	<5	0.15	<5	<5	7	<5	153	<0.2	<0.9	146	80.0
	2	<1	4320	<2	26800	<6	0.15	<6	<6	17	<6	126	<0.2	<1	108	74.5
	3	<0.8	6030	<2	21100	<4	0.28	<4	<4	14	4	89.5	<0.2	<0.8	102	77.5
	4	<1	4180	<2	29300	<5	0.099	<5	5	35	<5	130	<0.2	<1	164	81.5
	5	<0.8	4620	<2	24200	<4	<0.04	<4	5	15	<4	100	<0.2	<0.8	106	76.8
	6	<0.8	5510	<2	27100	<4	0.31	<4	<4	47	<4	116	<0.2	<0.8	136	77.4
	7	<1	5750	<2	23600	<5	0.22	<5	<5	12	<5	112	<0.2	<1	136	82.5
	8	<1	3670	<3	29300	<7	0.1	<7	<7	15	<7	157	<0.3	<1	147	82.3
	9	<1	6480	<3	27000	<7	0.24	<7	<7	19	<7	127	<0.3	<1	125	82.4
	10	<1	5680	<2	35500	<6	0.16	<6	<6	21	<6	198	<0.2	<1	154	78.9
	11	<0.8	4860	<2	25900	<4	0.12	<4	<4	17	<4	127	<0.2	<0.8	139	78.4
	12	<1	5540	<2	27500	<5	0.23	<5	10	15	<5	140	<0.2	<1	138	79.7
	13	<1	5120	<2	28000	<5	1.73	<5	<5	7	<5	123	<0.2	<1	125	80.1
	14	<1	4490	<2	25400	<6	0.13	<6	<6	15	<6	119	<0.2	<1	124	76.9
	15	<1	5110	<2	27700	<6	0.34	<6	<6	27	<6	152	<0.2	<1	144	75.1
	16	not available														
	17	<1	4920	<2	30600	<6	0.12	<6	<6	14	<6	145	<0.2	<1	166	81.9
Peamouth chub	18	<1	5810	<3	42400	<7	0.14	<7	<7	10	<7	416	<0.3	<1	303	79.9
	19	<1	6060	<2	36200	<5	0.25	<5	<5	19	<5	299	<0.2	<1	252	80.4
	20	<2	5880	<4	31400	<10	0.1	<10	<10	<10	<10	322	<0.4	<2	206	79.3
	21	<2	5220	<3	33300	<8	<0.08	<8	<8	18	<8	327	<0.3	<2	345	75.2
	22	<1	7120	<2	38800	<5	0.62	<5	<5	24	<5	298	<0.2	<1	221	81.3
	23	<1	4480	<2	25900	<6	0.34	<6	<6	17	<6	174	<0.2	<1	88	75.1
	24	<2	4780	<4	38400	<9	0.31	<9	<9	51	<9	481	<0.4	<2	249	76.0
	25	<1	7700	<2	43300	<5	0.27	<5	<5	12	<5	365	<0.2	<1	297	79.9
	26	<1	5860	<2	33500	<5	<0.05	<5	<5	18	<5	235	<0.2	<1	220	81.7
	27	<1	6490	<2	34300	<6	0.28	<6	<6	18	<6	259	<0.2	<1	237	79.6
	28	<1	5870	<2	31400	<6	0.14	<6	<6	10	<6	256	<0.2	<1	307	79.7

TABLE 30:

FISH LIVER METAL ANALYSIS - GOOSLY LAKE
June 17, 1990

	Compos-ite Number	Includes Fish Number	BIOICP AL UG/G	BIOICP AS UG/G	BIOICP BA UG/G	BIOICP BE UG/G	BIOICP CA UG/G	BIOICP CD UG/G	BIOGF CD UG/G	BIOICP CO UG/G	BIOICP CR UG/G	BIOICP CU UG/G	BIOICP FE UG/G	BIOHG HG UG/G	BIOICP K UG/G	BIOICP MG UG/G	BIOICP MN UG/G
Rainbow trout	1	1 + 2	<8	<8	<0.2	<0.2	380	<0.8	0.67	4.2	<0.8	374	1100	0.33	11000	770	6.6
	2	3 + 4	<8	<8	<0.2	<0.2	320	1.0	1.5	7.2	<0.8	471	1800	0.26	12000	790	6.9
	3	5 + 6	<5	<5	<0.1	<0.1	480	<0.5	0.46	3.5	<0.5	209	851	0.31	11100	710	4.4
	4	7 + 8	<10	<10	<0.2	<0.2	550	<1	0.69	3.3	1.0	221	870	0.22	11000	840	6.4
	5	9 + 10	<8	<8	<0.2	<0.2	870	<0.8	0.62	4.6	<0.8	171	1160	0.25	11000	760	6.2
	6	11, 12, 13	<6	<6	<0.1	<0.1	380	<0.6	0.67	3.0	<0.6	172	898	0.23	11000	740	5.5
	7	14+15+16+17	<7	<7	<0.1	<0.1	1200	<0.7	0.45	3.1	<0.7	111	804	0.24	12000	810	6.3

	Compos-ite Number	Includes Fish Number	BIOICP MO UG/G	BIOICP NA UG/G	BIOICP NI UG/G	BIOICP P UG/G	BIOICP PB UG/G	BIOGF PB UG/G	BIOICP SB UG/G	BIOICP SE UG/G	BIOICP SI UG/G	BIOICP SN UG/G	BIOICP SR UG/G	BIOICP TI UG/G	BIOICP V UG/G	BIOICP ZN UG/G	H2O %
Rainbow trout	1	1 + 2	2	4280	<3	13000	<8	<0.08	<8	24	10	<8	2.1	<0.3	<2	162	74.4
	2	3 + 4	<2	4500	<3	13300	<8	<0.08	<8	46	10	<8	2.0	<0.3	<2	166	74.7
	3	5 + 6	1	3370	<2	13200	<5	<0.05	<5	9	10	<5	1.4	<0.2	<1	116	72.2
	4	7 + 8	2	3320	<4	13100	<10	<0.1	<10	20	20	<10	3.3	<0.4	<2	207	76.0
	5	9 + 10	<2	4240	<3	12800	<8	<0.08	<8	21	10	<8	4.6	<0.3	<2	243	73.2
	6	11, 12, 13	<1	3230	<2	13000	<6	0.22	<6	13	14	<6	2.1	<0.2	<1	146	73.4
	7	14+15+16+17	<1	3390	<3	12200	<7	<0.07	<7	10	10	<7	5.6	<0.3	<1	166	73.1

Peamouth chub		A sample >0.1 g dry weight was not produced when Peamouth chub liver samples were combined:
	8	18 + 19 + 20 + 21 + 22
	9	23 + 24 + 25 + 26 + 27 + 28

TABLE 31

FISH KIDNEY METAL ANALYSIS - GOOSLY LAKE
June 17, 1990

	Composite Number	Includes Fish Number	BIOICP AL UG/G	BIOICP AS UG/G	BIOICP BA UG/G	BIOICP BE UG/G	BIOICP CA UG/G	BIOICP CD UG/G	BIOGF CD UG/G	BIOICP CO UG/G	BIOICP CR UG/G	BIOICP CU UG/G	BIOICP FE UG/G	BIOHG HG UG/G	BIOICP K UG/G	BIOICP MG UG/G	BIOICP MN UG/G
Rainbow trout	2	3 + 4	<9	10	0.4	<0.2	1400	<0.9	1.93	2.5	<0.9	5.6	552	0.49	7000	420	2.3
	3	5 + 6	<4	<4	0.1	<0.08	440	1.1	1.52	4.0	<0.4	8.0	946	0.53	16100	830	2.9
	5	9 + 10	<10	<10	0.8	<0.2	6360	1.0	3.11	3.9	<1	8.4	820	0.40	14000	1000	4.7
	6	11, 12, 13	<5	7	0.2	<0.1	500	0.8	1.98	4.0	1	8.4	933	0.39	15700	880	3.1
	7	14+15+16+17	<9	<9	<0.2	<0.2	870	2.0	3.07	4.1	<0.9	8.2	781	0.40	16000	1000	3.2
Samples 1 (1 + 2) and 4 (7 + 8) failed to produce a sample >0.1 g dry weight																	
Peamouth chub	8	18 + 19	<10	<10	9.4	<0.2	800	18	---	3.7	<1	8.1	673	2.3	10000	820	4.2
	9	20, 21, 22	<10	10	7.5	<0.2	550	13	---	3.1	<1	9.6	554	1.3	11000	710	4.1
	10	23+24+25+26	<10	<10	6.7	<0.2	1100	6.1	---	3.6	<1	8.9	537	1.5	15000	960	11
	11	27 + 28	<10	<10	7	<0.3	780	17	---	4.1	<1	9.4	703	1.8	15000	780	4.8

	Composite Number	Includes Fish Number	BIOICP MO UG/G	BIOICP NA UG/G	BIOICP NI UG/G	BIOICP P UG/G	BIOICP PB UG/G	BIOGF PB UG/G	BIOICP SB UG/G	BIOICP SE UG/G	BIOICP SI UG/G	BIOICP SN UG/G	BIOICP SR UG/G	BIOICP TI UG/G	BIOICP V UG/G	BIOICP ZN UG/G	H20 %
Rainbow trout	2	3 + 4	<2	1700	<4	7290	<9	<0.09	<9	<9	<9	<9	6.0	<0.4	<2	93.5	77.6
	3	5 + 6	<0.08	3350	<2	14600	<4	0.12	<4	<4	15	5	2.6	<0.2	<0.8	141	78.9
	5	9 + 10	<2	3560	<4	14400	<10	<0.1	<10	<10	<10	<10	29.3	<0.4	<2	210	75.5
	6	11, 12, 13	<1	3310	<2	13400	<5	<0.05	<5	<5	14	<5	3.2	<0.2	<1	147	78.9
	7	14+15+16+17	<2	2880	<4	12900	<9	<0.09	<9	<9	10	<9	4.8	<0.4	<2	165	75.7
Samples 1 (1 + 2) and 4 (7 + 8) failed to produce a sample >0.1 g dry weight																	
Peamouth chub	8	18 + 19	<2	2520	<4	9460	<10	<0.1	<10	<10	<10	<10	4.2	<0.4	<2	329	78.7
	9	20, 21, 22	<2	2220	<4	9760	<10	0.22	<10	<10	<10	<10	3.0	<0.4	<2	395	77.3
	10	23+24+25+26	<2	2200	<5	11200	<10	0.26	<10	<10	<10	<10	5.2	<0.05	<2	365	76.8
	11	27 + 28	<3	2400	<5	11600	<10	<0.1	<10	<10	<10	<10	3.6	<0.05	<3	404	71.2

TABLE 32: GOOSLY LAKE METAL CONTAMINATION FACTOR (Cf)

A) Baseline level determined by lake values from literature

Element	1987 (n=8)	1988 (n=5)	1989 (n=5)	1990 (n=5)
Arsenic (15 µg/g)	0.3	3.53	2.87	3.33
Cadmium (1.0 µg/g)	3.5	0.9	1.0	0.8
Chromium (90 µg/g)	0.4	0.36	0.44	0.41
Copper (50 µg/g)	2.3	1.92	1.72	2.18
Lead (70 µg/g)	1.0	0.71	0.54	0.37
Mercury (0.25 µg/g)	-	1.55	2.95	1.04
Zinc (175 µg/g)	1.58	1.71	2.09	1.71
$\sum Cf_i$	9.38	10.67	11.61	9.84

Based on Håkanson (1980)

B) Baseline level determined from sediment cores

Element	1987 (n=8)	1988 (n=5)	1989 (n=5)	1990 (n=5)
Arsenic (9.7 µg/g)	0.88	5.46	4.43	5.15
Cadmium (1.0 µg/g)	4.18	1.05	1.18	0.94
Chromium (90 µg/g)	0.97	0.81	0.98	0.92
Copper (50 µg/g)	1.16	0.96	0.87	1.09
Lead (70 µg/g)	8.65	6.17	4.69	3.2
Mercury (0.25 µg/g)	-	0.94	1.48	0.63
Zinc (175 µg/g)	0.80	0.87	1.06	0.87
$\sum Cf_i$	16.64	16.26	14.69	12.8

DRAFT

TABLE 33: EQUITY MINE AMD PUMP RECORDS

Year	AMD Discharged to Buck Creek
1985	634,000 m^3
1986	468,600 m^3
1987	268,200 m^3
1988	no discharges to Buck Creek
1989	78,400 m^3 + [illegible]
1990	804,900 m^3

The Risk Factor describes the potential ecological risk of a given contaminant in the lake, according to the contamination factor and the toxic response of the element. The toxic response is a relationship between the toxicity of the element and the bioproduction index of the lake (Håkanson, 1980). The bioproductive index for Goosly Lake was defined as 1.97 (Godin, 1988). The Risk Index (RI) is the summation of all risk factors. Table 34 shows the risk factor and index for both methods of assessing the contamination factor.

The risk index was based on 8 contaminants, however only 7 were used 1988 to 1990. Accordingly, Håkanson's evaluation scale was adjusted to allow an appreciation of Goosly Lake potential ecological risk:

RI < 130	Low ecological risk for the lake
130 < RI < 260	Moderate ecological risk for the lake
260 < RI < 525	Considerable ecological risk for the lake
RI > 525	Very high ecological risk for the lake

DRAFT

TABLE 34: GOOSLY LAKE RISK INDEX

A) Risk index determined by contamination factor based on literature values

Element	1987 (n=8)	1988 (n=5)	1989 (n=5) (n=5)	1990
Arsenic	3.00	35.3	28.7	33.3
Cadmium	167.28	43.01	47.79	38.23
Chromium	1.28	1.14	1.39	1.30
Copper	18.48	15.3	13.71	17.37
Lead	7.97	5.66	4.30	2.94
Mercury	-	157.36	299.48	105.58
Zinc	2.52	2.72	3.33	2.74
RI	200.5	260.48	398.7	201.44

B) Risk index determined by contamination factor based on sediment cores

Element	1987 (n=8)	1988 (n=5)	1989 (n=5)	1990 (n=5)
Arsenic	8.8	54.6	44.3	51.5
Cadmium	199.76	50.18	56.39	44.92
Chromium	3.08	2.58	3.12	2.93
Copper	9.24	7.65	6.93	8.68
Lead	68.94	49.17	37.40	25.5
Mercury	-	95.43	156.25	63.95
Zinc	1.27	1.38	1.68	1.38
RI	291.09	260.99	300.07	198.86

It should be noted that the record for 1987 is not based on the same number of contaminants since mercury was not determined in 1987. In 1987 the lake risk factor was moderate based on literature contamination factors, but considerable based on the sediment core data. This could be a reflection of a spill of AMD to Bessemer Creek of up to 8,172 tonnes which was reported in April 1986.

The risk index based on sediment core data shows that the lake ecological risk was considerable up to 1990 when it decreased to a moderate level. In 1989, Equity Silver updated the AMD collection system to intercept groundwater seepages flowing toward Buck Creek. The improvements associated with the reduction of discharges should result in the amelioration of the conditions in Goosly Lake. These changes in ecological risks are consistent with the sediment bioassays results. It is hypothesized that Goosly Lake sediments in 1992 should produce a risk index similar or better than in 1990.

5.0 CONCLUSIONS

Equity Silver mine's impact on Goosly Lake was evaluated from various perspectives. Water quality, sediment, bioassay, plankton population, and fish tissue samples were collected from four different surveys in order to determine the health of the lake.

Water quality showed that the copper levels were elevated and above the CCME guidelines. However, complexing capacity of Buck Creek waters was sufficient to chelate copper and prevent toxic effect. Sediment cores showed that the copper concentrations in the lake were not unduly elevated and that Goosly Lake has historically been elevated for this element.

Sediment chemistry showed changes in concentration levels from the early surveys in 1987 to the more recent survey in 1990. These levels reflected the mining activity in terms of treated AMD releases and effluent spills. Changes in chemical speciation from 1987 and 1988, especially for cadmium, give added information regarding the effect of water quality on sediment and on aquatic biota. The high allochthonous material discharge to the lake is reflected by the high sedimentation rate (10.6 mm/year). This also provides a high contamination recovery potential for the lake because of the fast rate at which sediment layers are buried.

Bioassay studies performed in 1988 showed sublethal effects such as inhibition of reproduction in Ceriodaphnia, enzyme inhibition, and genotoxicity. Two years later, emergence tests using Chironomus tentans failed to show evidence of sublethal toxicity. The reduction of sediment contamination is reflected in the biological response from the bioassays.

No conclusive results could be produced from the benthic and zooplankton populations due to the high variability of these measurements. The inability to track these population through time allows only a description of the presence and absence of certain species and their relative abundance. This information could be added to baseline information to evaluate the mine's performance after abandonment, but contains too many uncertainties for the characterization of population alteration from the mine's influence.

Fish tissue metal levels showed that trout populations are not negatively affected by the mine discharges. The significance of metal concentrations in peamouth chub tissues has not been determined. This species has low values from a sport fisheries aspect but could be used as a monitoring species.

The utilization of contamination risk index showed improvement of the sediment quality in Goosly Lake. This tool may be useful in tracking Goosly Lake conditions, since several other approaches are in agreement with the technique.

References

6.0 REFERENCES

Agbeti, M. and M. Dickman. 1989. Use of Lake Fossil Diatom Assemblage to Determine Historical Changes in Trophic Status. Can. J. Fish. Aquat. Sci., 46: 1013-1021.

Ahlf, W., W. Calmano, and U. Förstner. 1984. Correlation Between Chemical and Biological Evaluation Procedures for the Determination of Trace Metal Availability from Suspended Solids. In: Interaction Between Sediment and Water. P.G. Sly (ed.), Proc. 3rd International Symposium, Geneva, pp. 140-143.

Anonomous. 1979. Laboratory Manual. Department of the Environment, Environmental Protection Service. Department of Fisheries and Oceans, Fisheries and Marine Service.

Blaise, C., R. Legault, N. Bermingham, R. van Collie, and P. Vasseur. 1984. Microtest mesurant l'inhibition de la croissance des algues (C150) par le dosage de l'ATP. Sciences de Technique de l'eau 17.

Boyle, T.P., G.M. Smillie, J.C. Anderson, and D.R. Beeson. 1990. A Sensitivity Analysis of Nine Diversity and Seven Similarity Indices. Res. J. Water Pollut. Control Fed., 62(6): 749-762.

Brock, D.A. 1977. Comparison of Community Similarity Indexes. J. Wat. Pollut. Fed., 49 (12): 2488-2494.

Calmano, W., W. Ahlf, and U. Förstner. 1988. Study of Metal Sorption/ Desorption Processes on Competing Sediment Components with a Multichamber Device. Envir. Geol. Water Sci., 11(1): 77-84.

Canadian Council of Resource and Environment Minsters. 1987. Canadian Water Quality Guidelines. Ottawa.

Cornwell, J.C. 1986. Diagenetic Trace-Metal Profiles in Arctic Lake Sediment. Environ. Sci. Technol., 20(3): 299-302.

Dutka, B.J. 1988. Priority Setting of Hazards in Waters and Sediments by Proposed Ranking Scheme and Battery of Tests Approach. German Journal for Applied Zoology, pp. 303-316.

Dutka, B.J., K.K. Kwan, K. Jones, and R. McInnes. 1987. Battery of Screening Tests Approach Applied to Sediment Extracts. NWRI Contribution No. 87-134. River Research Branch, National Water Research Institute, Burlington.

Fast, A.W., R.G. Wetzel. 1974. A Close-Interval Fractionator for Sediment Cores. Ecology, 55: 202-204.

Förstner, Ulrich. 1987. Sediment-Associated Contaminants - An Overview of Scientific Bases for Developing Remedial Options. Hydrobiologia, 149: 221-146.

Godin, B. 1988. Water Quality and Sediment Analysis for the Buck Creek System Adjacent to the Equity Silver Mine Near Houston, B.C. - May 21 and June 19-20, 1987. Regional Data Report 88-01. Environmental Protection, Environment Canada.

Håkanson, L. 1976. A Bottom Sediment Trap for Recent Sedimentary Deposits. Limnol. Oceanogr., 21: 170-174.

Håkanson, L. 1980. An Ecological Risk Index for Aquatic Pollution Control. A Sedimentological Approach. Water Research, 14: 975-1001.

Hutchinson, G.E. 1957. A Treatise on Limnology, Volume 1 - Geography, Physics, and Chemistry. John Wiley and Sons, New York. 1015 pp.

Johnson, M.G., L.R. Culp, and S.E. George. 1986. Temporal and Spatial Trends in Metal Loadings to Sediments of the Turkey Lakes, Ontario. Can. J. Fish. Aquat. Sci., 43: 754-762.

Joshi, S.R., and R.W. Durham. 1976. Determination of 210Pb, 226Ra and 137Cs in Sediments. Chemical Geology, 18: 155-160.

Joshi, S.R. 1989. Common Analytical Errors in the Radiodating of Recent Sediments. Environ. Geol. Water Sci., 14(3): 203-207.

Karlsson, S., K. Håkansson, B. Allard. 1987. Simultaneous Dissolution of Organic Acids in Sequential Leaching of Sediment Bound Trace Metals. J. Environ. Sci. Health., A22(6): 549-562.

Kemp, A.L.W., R.L. Thomas, C.I. Dell, and J.-M. Jaquet. 1976. Cultural impact on the geochemistry of sediments in Lake Erie. J. Fish. Res. Board Can., 33: 440-462.

Krishnaswamy, S., D. Lal, J.M. Martin, M. Meybeck. 1971. Geochronology of Lake Sediment. Earth and Planetary Science Letters, 11: 407-414.

Lion, L.W., R.S. Altman and J.O. Leckie. 1982. Trace Metal Sorption Characteristics of Estuarine Particulate Matter: Evaluation of the Contribution of Fe/Mn Oxide and Organic Surface Coatings. Environ. Sci. Technol., 16: 611-618.

Nevisis, A.E. 1985. Measurement of 210Pb Atmospheric Flux in the Pacific Northwest. Health Phys., 48(2): 169-174.

Nirel, P.M.V., and F.M.M. Morel. 1990. Pitfalls of Sequential Extractions. Water Res. 24 (4): 1055-1056.

Pennak, R.W. 1978. Freshwater Invertebrates of the United States, 2nd ed. John Wiley and Sons, New York. 803 pp.

Pielou, E.C. 1975. Ecological Diversity. John Wiley and Sons, Toronto. 165 pp.

Rubic, I. 1982. Theoretical aspects of the direct titration of natural waters and its information yield for trace metal speciations. Anal. Chim. Acta, 140: 99-113.

Rao, S.S. 1988. Ceridaphina reticulata Seven-day Survival and Reproduction Test. Tox. Assess., 3: 239-244.

Salomons, W. 1980. Adsorption Processes and Hydrodynamic Conditions in Estuaries. Environ. Technol. Letters, 1: 356-365.

Tessier, A., P.G.C. Campbell, and M. Bisson. 1979. Sequential Extraction Procedure for the Speciation of Particulate Trace Metals. Analytical Chemistry, 51(7): 844-851.

Wilkes, B.D. and D.B. Maclean. 1987. The Effect of Equity Silver Mine on Goosly Lake. Environmental Section Report 87-01. Waste Management Branch, Ministry of Environment and Parks, Northern Region, Smithers. 55p.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the support received from Gerry Mitchell, Vivian Chamberlain, and Isobel Booth in preparing for and carrying out these surveys. Peter Kilion diligently fabricated the sediment traps and the core extruder. Bernie Dutka and Trevor Reynoldson of NWRI were kind enough to perform the sediment bioassays. Chris Millard spend a lot of time developing sequential extraction capability at the EP chemistry lab. Mike Hagen's help was invaluable in producing the final report. I thank you all.