A Biological Assessment of Benson Lake Following Cessation of Deep Lake Tailings Disposal

A BIOLOGICAL ASSESSMENT OF BENSON LAKE FOLLOWING CESSATION OF DEEP LAKE TAILINGS DISPOSAL

by

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Vancouver, B.C.

Surveillance Report EPS 5-PR-74-2

July, 1974

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ABSTRACT

Post mine operation conditions in Benson Lake were documented in November, 1973. Turbidity measurements showed a marked improvement in lake water clarity compared to levels recorded when the mine disposed of tailings in the lake. Total metal concentrations in lake water and fish tissue remained unchanged. Examination of the contents of trout stomachs indicated that their food supply was obtained from sources othern than the lake bottom. Improvements in lake productivity and recolonization by benthic organisms is expected to take several years.

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1. INTRODUCTION

Coast Copper Company Ltd., a Cominco operation, located at Benson Lake in the north-central sector of Vancouver Island, initiated production of a relatively high grade ore deposit (mean grade 2.02% Cu, Canada Minerals Yearbook, 1971), in August 1962. Various factors, including high wages, low copper prices, and diminishing high grade ore forced the decision to terminate production in January 1973. Prior to shutdown the underground operation and adjoining concentrator processed an average 1,500 tons of copper ore per day.

During the life of the mine, the company was permitted to discharge tailings directly into Benson Lake, because of a lack of suitable terrain for tailings impoundment. From the outset, problems arose with turbidity through most of the year due to poor settling characteristics of the finer colloidal tailings fractions, a problem not uncommon with underwater and deep lake tailings disposal (Duncan, 1970).

At the request of the former Department of Fisheries, the following changes were made over a period of time in an attempt to effect improved settling of the tailings slurry:

(a) The tailings discharge point was moved to a deeper portion of the lake to prevent blockage at the downspout

from tailings buildup.

(b) A flocculating agent, Alchem D176, was mixed with the tailings at the lake downspout to help precipitate the finer fractions.

(c) Surveillance and maintenance of the discharge line was increased to reduce the risk of spills, particularly during the winter months when breaks in the effluent and flocculating lines sometimes went unnoticed for extended periods of time.

Despite these changes, turbidity in the lake remained a problem and was especially noticable during the winter months when the lake was isothermal. It has been suggested that, during summer stratification, the thermocline functioned as a barrier above which colloidal tailings were not found due to density differences. After the fall turnover of the lake the water mass is homogeneous and colloidal tailings were again dispersed throughout the entire water column (Kussat et al, 1972).

A survey of the benthic fauna of Benson Lake conducted in 1967 showed the entire lake bottom to be covered with tailings and completely void of benthic organisms. Turbidity was so extensive that at times turbid waters extended as far downstream as Alice Lake (see Figure 1). Examination of the Lower Benson River also revealed a layer of tailings fines as well as benthic organisms indigenous to turbid water conditions.

The Environmental Protection Service undertook a "follow-up

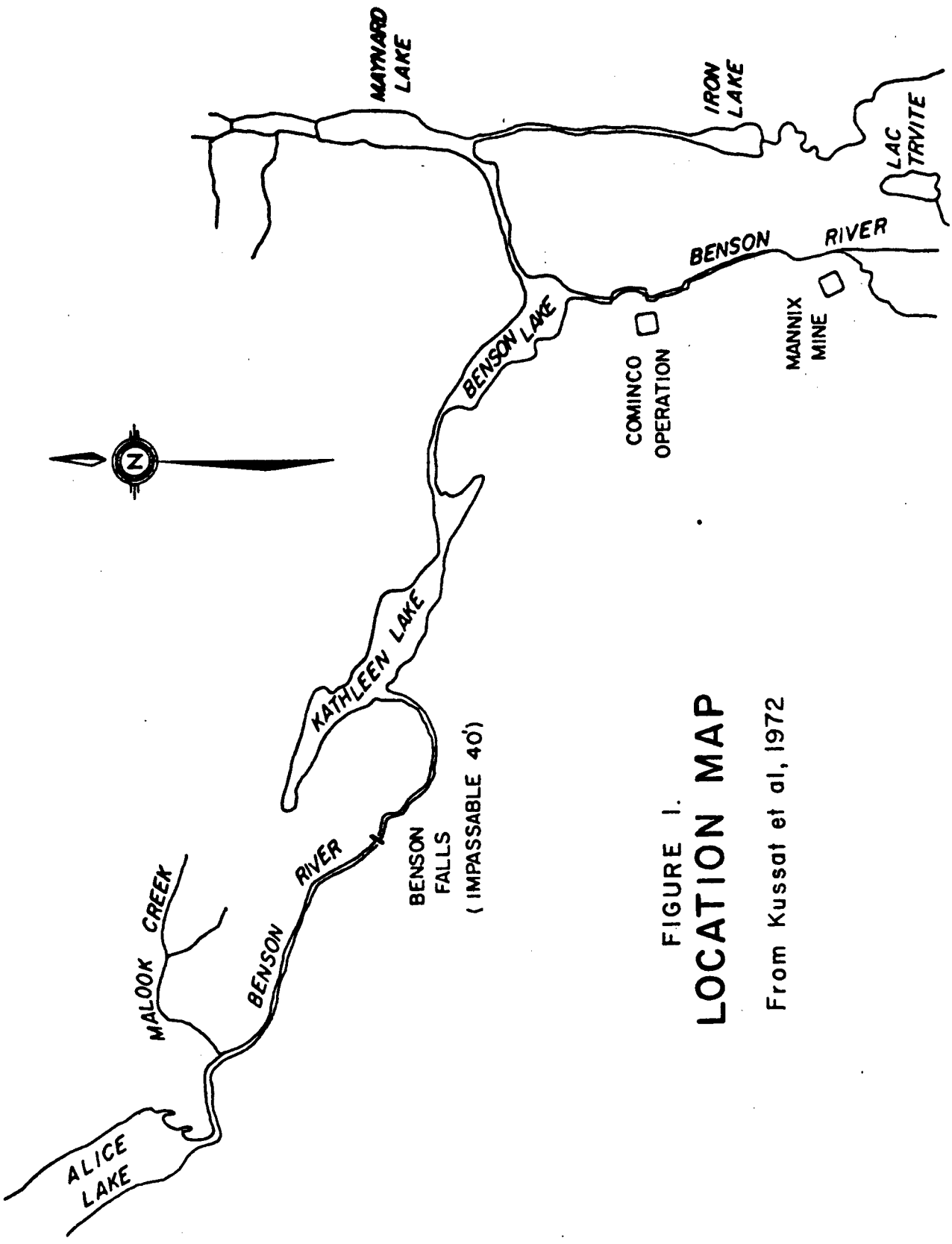

FIGURE 1.

LOCATION MAP

From Kussat et al, 1972

survey" of Benson Lake to document possible improvements in the lake since mine closure. Sampling was conducted on November 7, 1973 after the fall turnover, which normally occurs in September. This period coincides with the period of greatest lake turbidity observed during the mine operation.

2. MATERIALS AND METHODS

Three sampling stations, established by Cominco for earlier monitoring, were used for the sampling program (see Figure 2).

2.1 Water Chemistry and Physical Conditions

A six litre Van Dorn bottle lowered by a cable drawn through a meter wheel was used to acquire water samples from the bottom, middle and surface levels at each station. From the six litre sample, three 1 litre subsamples were placed in polyethylene bottles and treated in the following manner:

- 1 litre, refrigerated for residue content,
- 1 litre, refrigerated for turbidity measurement,
- 1 litre, preserved with 5 mls concentrated HNO_3 for extractable heavy metal content.
- Direct aspiration and solvent extraction in conjunction with a Jarrell-Ash 82-800 atomic absorption unit was employed in the analyses.

The analytical work was performed at the Environment Canada Water Quality Laboratory in West Vancouver.

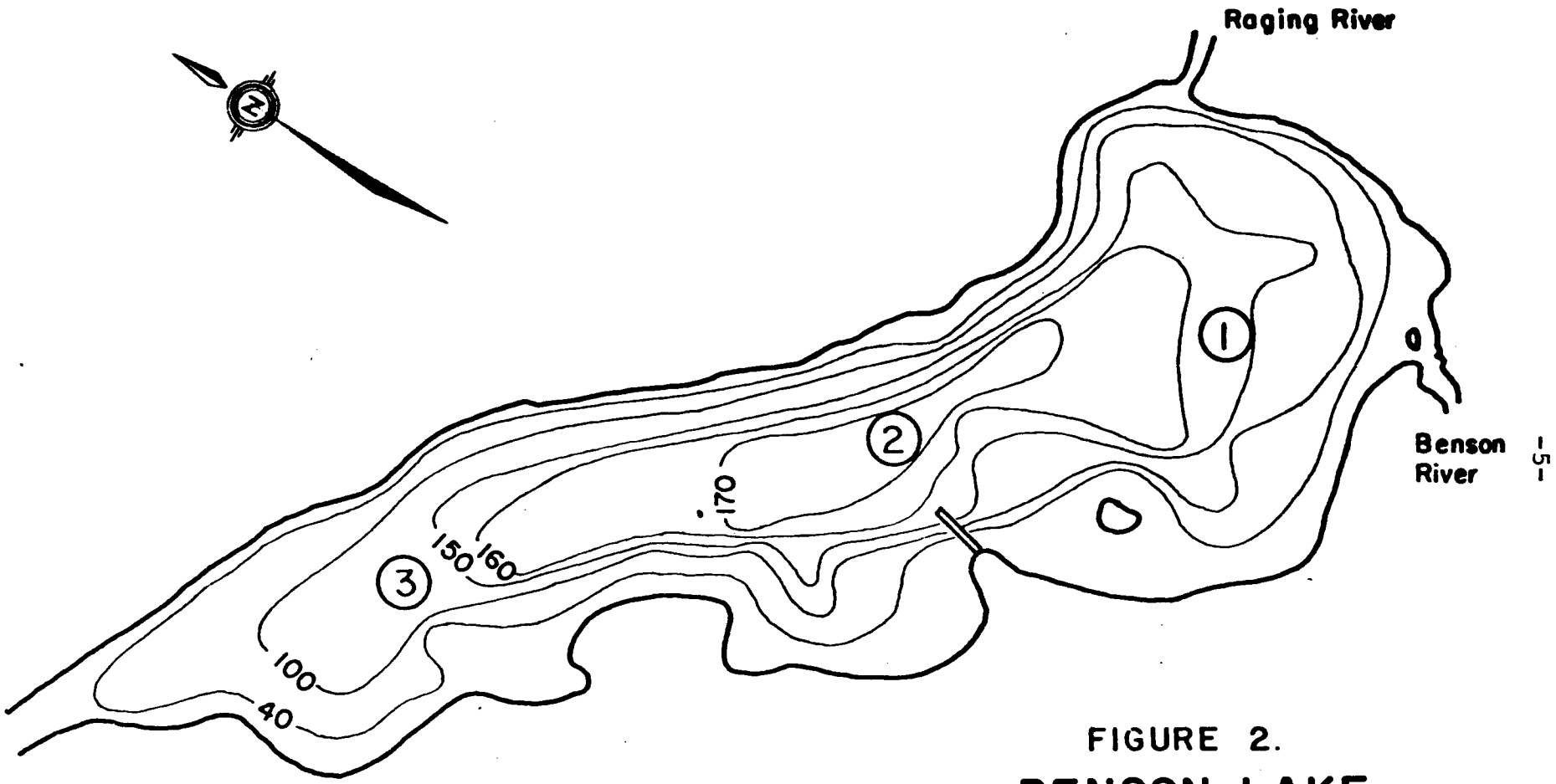

FIGURE 2.

BENSON LAKE

APPROX. SCALE 1" = 1100'

JULY 1974

From Kussat et al, 1972

A thermometer and the appropriate Hach kits were used to determine the pH, D.O. and temperature from the remaining three litre samples.

Secchi disc readings were also taken at each station using a standard 20 cm weighted disc with alternating black and white quadrants.

2.2 Biological Assessment

A 50 foot, 1.5 inch mesh, monofilament gillnet was set in the lake for a 24 hour period. Of the 16 fish caught, 11 were quick frozen for heavy metal analysis at Environment Canada Water Quality Laboratory. Each of the remaining five (4 salmo gairdneri and 1 salmo clarki) were subjected to the following analyses:

(a) weighed (grams);

(b) measured (fork length, cm);

(c) aged by the "preferred scale", or second scale above the lateral line on a diagonal column which extends from the posterior insertion of the dorsal fin.

(d) the stomach was removed and preserved in 10% formalin for content analyses.

(e) a large section of flesh was quick frozen. Heavy metal analyses were subsequently performed at Cominco's Waste Control Laboratory at Trail.

3. RESULTS AND DISCUSSION

3.1 Water Chemistry and Physical Parameters

The lake was found to be in an isothermal condition (temperature 6°C throughout). The homogeneous pH and dissolved oxygen levels, 7.0 and 12 ppm respectively, confirmed this finding.

Benson Lake Secchi disc values averaged 6 feet shortly after fall turnover in November 1968 and 1970. During the same isothermal period of November 1973 the mean was 16.5 feet. Maynard Lake, which was used as a control to the Benson Lake monitoring, had Secchi disc values in the same order of magnitude (18 feet) in November 1967 and 1968. This lake was not monitored in 1973.

Turbidity values for the three stations on November 7, 1973 (isothermal period) and September 9, 1971 (amid a fall turnover) are presented in Table 1. Measurements in 1973 were made by the Nephelometric method, which measures scattered light from a formazin polymer standard (F.T.U.'s, Formazin Turbidity Units). The 1971 turbidity measurements were made with a Jackson Candle Turbidimeter (J.T.U.'s Jackson Turbidity Units).

An approximate correlation exists between these two measurements. "A formazin suspension of 40 units has an

approximate turbidity of 40 units when measured on a candle turbidimeter; therefore, turbidity units based on the formazin preparation will approximate those derived from the candle turbidimeter but will not be identical to them." (APHA, 1971). F.T.U.'s of 1 or less may be considered essentially clear.

TABLE 1. TURBIDITY VALUES FOR SEVERAL DEPTHS AT STATIONS 1, 2, AND 3 - NOVEMBER 7, 1973 AND SEPTEMBER 9, 1973.

Station	Depth (Meters)	Turbidity November 7/73 F.T.U.'s	Turbidity September 9/71 J.T.U.'s
1	0	.65	3
	20	.57	4
	40	.45	5
2	0	.57	3
	25	.46	4
	50	.51	14
3	0	.45	3
	15	.56	4
	30	.65	4

During normal flow rates the Upper Benson River has been reported to carry approximately 50 mg/l of sediment, etc. into Benson Lake (Kussat et al, 1972). After heavy rains and resulting freshets this level increases significantly. 1973 residues in the lake (see Table 2) are low and representative of clear water. The high content of non-filterable residue at the surface of station one, possibly resulted as the direct effect of the Upper Benson River. The November 1973 turbidity measurements indicate that the colloidal tailings have settled and that Benson Lake clarity may have returned to pre-mine conditions.

TABLE 2. RESIDUE CONTENT OF BENSON LAKE -- NOVEMBER 7, 1973

Station	Depth (Meters)	Total Residue (mg/ℓ)	Filterable Residue (mg/ℓ)	Non-Filterable* Residue (mg/ℓ)
	0	75	55	20
1	20	52	48	4
	40	55	55	0
	0	51	50	1
2	25	50	50	0
	50	50	50	0
	0	50	51	0
3	15	63	62	1
	30	51	52	0

* Obtained by subtraction.

The heavy metal content of Benson Lake water was found to be homogeneous throughout. Heavy metal analysis for November 1973 and February 1971 are presented in Table 3.

TABLE 3. MEAN CONCENTRATION OF SOME METALS IN BENSON LAKE WATER - FEBRUARY 1971 AND NOVEMBER 1973.

Metal	Concentration (ppm)	
	February 1971 Cominco Analyses	November 1973 Envir. Canada Analyses
Hg	<0.00005	<0.0008
Cu	<0.005	<0.03
Zn	0.06	<0.03
Pb	<0.01	<0.03
Cd		<0.03

< denotes the detection limit

Zinc levels which were earlier reported high appear to have subsided. Concentrations of .15 ppm of zinc are lethal to adult trout, trout fingerlings and salmon fry over a 24-hour period. Concentrations of greater than .03 ppm cadmium acts synergistically with zinc and other metals to increase toxic effects (Water Quality Criteria, 1973). These and other metals are equally or more toxic in soft waters such as Benson Lake than in harder waters (American Fisheries Society, 1970).

3.2 Biological Assessment

Deep lake disposal of mine tailings, although a theoretical "out-of-sight" solution to mines in locations without adequate space for land disposal, appears to present a number of ecological problems. Turbidity and high levels of suspended solids cause stress and are a considerable nuisance to the biota, but most research on underwater disposal has found that the greatest detrimental effects are caused not by toxicity but by burial of benthic flora and fauna (Duncan, 1970). Dredge samples from 1967 and 1972 indicated that the bottom of Benson Lake was covered by mine tailings and was void of benthic organisms. Benson Lake in its present state appears to be in an oligotrophic condition (sparse productivity and sterile substrate). The degree of trophication (in this case natural succession on the tailings sands) required to support limited recolonization will probably take many years.

The small size of four-year-old Benson Lake trout may be partially related to the lack of a resident benthic invertebrate population. Analyses of a small sample of fish stomachs indicated that these fish rely largely upon outside sources of food (i.e. drift from the Upper Benson and Raging Rivers). Stomachs of fish caught in

1968 (Kussat et al, 1972) and November 1973 contained juvenile invertebrates normally found in clear, cold streams (trichoptera, ephemeroptera), adult invertebrates caught on the lake surface and other trout. The age, size and food of the fish captured in 1973 are presented in Table 4.

The vastly increased surface area of the ground ore leaves the remaining metal content of the tailings sands exposed to leaching by oxidative and bacterial action. These metals after being released to the aquatic environment become assimilated into plant and animal tissue at concentrations several times greater than in the immediate environment. Some metals particularly lead and mercury, are assimilated in an accumulative manner (additive) and can cause lethal and sublethal effects (American Fisheries Society, 1970).

Heavy metal concentrations of adult Benson Lake trout caught in 1971 and 1973 are presented in Table 5. Also shown are permissible levels taken from the Canadian Food and Drug Act Regulations on poisonous substances in food (1968)*. The present results show little significant change from Benson and Maynard Lake specimens of 1971, and in all cases are below levels specified by the Food and Drug Act of 1968.

* Now under active review.

TABLE 4. BENSON LAKE TROUT -- NOVEMBER 7, 1973.

Species	Wt. (grams)	Length (cm)	Age (years)	Stomach Contents
Salmo clarki (cutthroat)	463.1	32.2	4	1 - 2" trout 1 - trichoptera philopotamidae (a)
Salmo gairdneri (rainbow)	123.2	23.4	4	2 - diptera (l) 1 - trichoptera philopotamidae (a) 1 - ephemeroptera baetidae (l)
Salmo gairdneri (rainbow)	98.6	20.2	4	2 - trichoptera rhycophilidae (l) 1 - trichoptera hydropsychidae (l)
Salmo gairdneri (rainbow)	102.9	21.8	5	1 - coleoptera (a) 5 - diptera tendipedidae (a) 1 - diptera tendipedidae (l) 1 - hemiptera (a)
Salmo gairdneri (rainbow)	156.2	26.2	--	1 - coleoptera (a) 1 - diptera (a) 2 - trichoptera rhycophilidae (l) 2 - hemiptera (a)

(a) = adult

(l) = larval

TABLE 5. SOME HEAVY METAL CONCENTRATIONS IN BENSON LAKE TROUT, 1971 AND 1973 AND LIMITES SPECIFIED BY THE CANADIAN FOOD AND DRUG REGULATIONS ON POISONOUS SUBSTANCES IN FOOD (1968).

Metal	Concentration ppm wet wt*			
	1971	1973		1968
	Cominco Analysis	Cominco Analysis	Envir. Canada Analysis	Food and Drug Act+
Hg	0.1	0.095	0.070	.5
Cu	0.2	0.5	<0.19	100
Zn	6.5	5.4	3.9	100
Pb	0.1	0.5	--	10
Cd	0.1	0.1	0.58	--

< denotes detection limit

* all results represent averages of sample.

+ regulations for marine and freshwater fish products.

4. SUMMARY

The mine ceased operation (lake disposal of tailings) in January 1973. This "post-operational" survey was designed to document certain environmental conditions in Benson Lake and compare with "operational" survey results.

(a) On November 7, 1973 temperatures, pH and dissolved oxygen levels were uniform throughout the lake.

(b) Benson Lake 1973 Secchi disc reading (16 to 17 feet) showed a 10-foot increase over the same isothermal periods of 1968 and 1970 and were similar to the

readings obtained in Maynard Lake in 1967 and 1968.

(c) Total residue content of the lake approximated the contribution made by the Upper Benson River. Therefore little if any can be attributed to suspended colloidal tailings fines from the Coast Mining operation.

(d) Lake clarity, as measured by the Nephelometric methods depicted clear lake conditions and further substantiated the low residues and high secchi measurements recorded.

(e) Little change in heavy metal content of lake water has occurred since 1971, however, zinc levels declined slightly.

(f) 1973 heavy metal analyses of four- and five-year-old trout muscle tissue contained equivalent metal levels as did 1971 specimens. It is therefore concluded that heavy metals bound up in the tailings sands are not being assimilated in the food chain to any significant extent.

(g) Stomachs of four-year-old trout contained organisms from sources other than the lake bottom. Improvement in the productivity of the lake and recolonization by benthic organisms is expected to take several years.

5. ACKNOWLEDGEMENTS

The analytical expertise of Environment Canada's Water Quality Laboratory and Cominco's Waste Water Control Laboratory for the various analyses is acknowledged.

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