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**AN INVESTIGATION INTO THE EFFECTS OF  
A LEAD-ZINC MINE ON THE AQUATIC ENVIRONMENT  
OF GREAT SLAVE LAKE**

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APRIL 17, 1972

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## INTRODUCTION

In recent years, the Northwest Territories have witnessed a large-scale increase in exploration for mining of new mineral deposits. Several such deposits have been discovered and only await favourable market values or access routes to be developed.

Despite increased research efforts, our knowledge of the Arctic or Sub-Arctic environment is frequently inadequate to ensure that ecological alterations are minimized during new mining operations. One of the prime areas of concern in this respect is the disposal of mill tailings.

This report explores some of the affects that mine effluent is having on the aquatic environment of Great Slave Lake. It is hoped that the findings presented here will be of value, not only in rectifying an existing situation, but in establishing baselines for the control of mine pollution throughout the Northwest Territories.

## DESCRIPTION OF THE AREA

Lead-zinc deposits at Pine Point, Northwest Territories comprise known ore reserves of 42.5 million tons, averaging 7% zinc and 2.6% lead in a 20 by 4 mile belt of barrier carbonate of Middle Devonian age, now exposed or at shallow depths amenable to open pit mining. Ore bodies that form an integral part of the upper Pine Point and Presqu'ile formations are elongate lens shaped bodies ranging from a few hundred thousand to 10 million tons in size (Jackson and Folinsbee, 1969).

The Pine Point mine site is located approximately 110 miles south of Yellowknife and 56 miles east of the town of Hay River (Figure 1). Position of the mill is roughly six miles south of the south shore of Great Slave Lake. This area is predominantly muskeg and generously scattered with small shallow lakes. Slope of the land from mill to lake is roughly one foot per mile to the north-west, resulting in a poorly defined drainage system. Primary vegetative cover is black spruce.

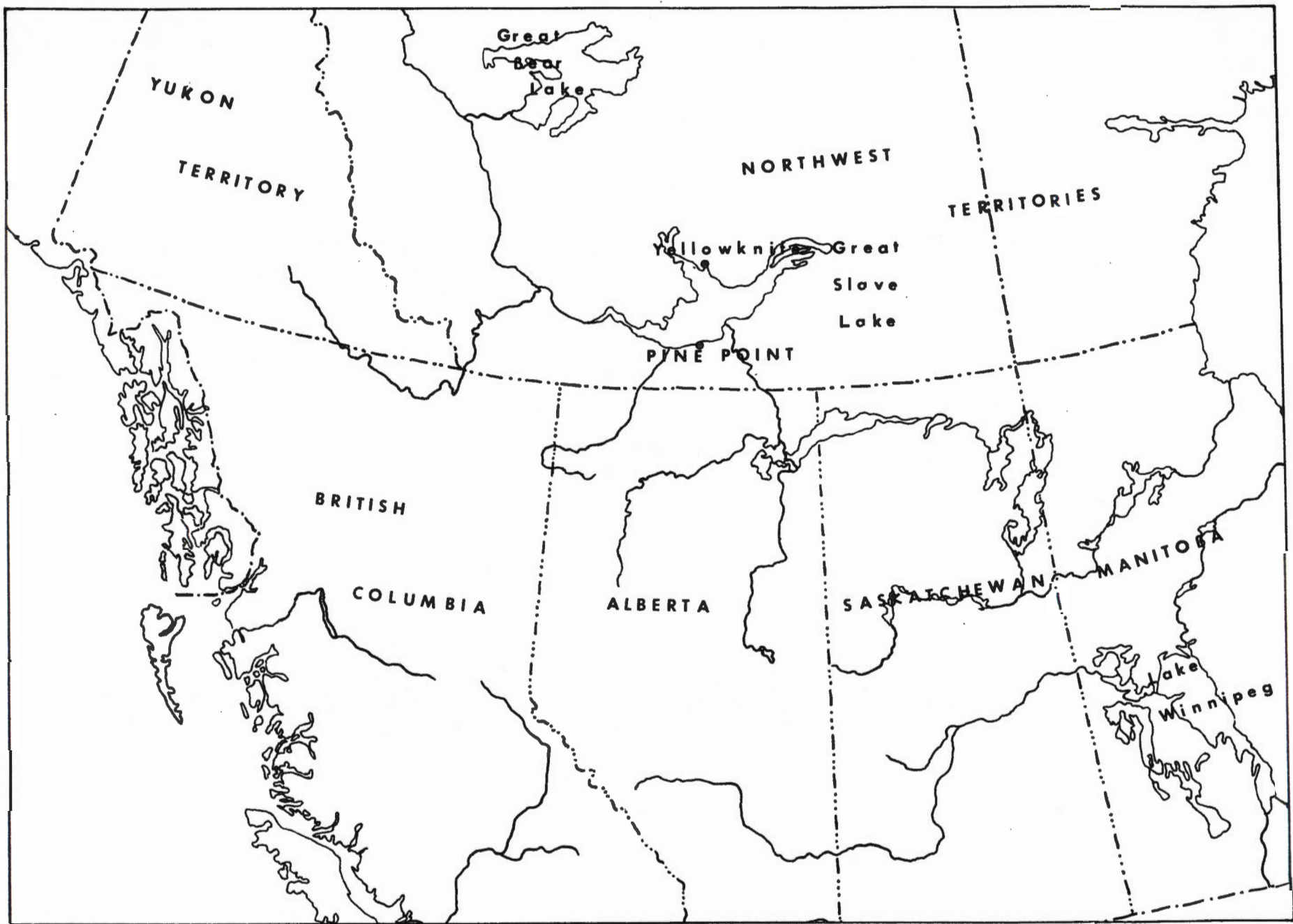


Figure 1. Pine Point, N.W.T.

## MINING AND CONCENTRATING PROCESSES

Lead-zinc ores are mined from several open pits in the vicinity of the mill (Figure 2). Mined ore is hauled by truck and stockpiled nearby. Feeding through primary and secondary crushers reduces the product to minus 3/4 inch. Eventually, crushed ore is fed into three identical grinding circuits consisting of a rod mill, ball mill and four cyclones. Water is added at this stage to create a slurry of 80% solids. Most particles leaving the cyclones are less than 0.075 mm and then enter the floatation circuit.

Slurry enters a two stage floatation process from which lead and zinc concentrates are produced. Several reagents are added at this stage to control the process. Lime (calcium hydroxide), sodium cyanide and sodium sulphite are used to depress zinc and iron sulphides and to float lead sulphide. Zinc sulphide is floated off by adding copper sulphate. Sodium isopropyl xanthate is used as a collector in both lead and zinc floatations.

Dewatering of the concentrate is accomplished through thickeners, vacuum drum filters and dryers. About 1300 tons of zinc concentrate (57% zinc) and 350 tons of lead concentrate (75% lead) are produced daily. Concentrates are shipped by rail to various smelters.

Water used by the townsite and in the milling processes originates from a series of wells near the mill. Process waters consisting of thickener overflow and filtrate from the vacuum filters are recycled in the plant. There is no recycling of mill tailings. Tailings are dumped from a "T" shaped trestle (Figure 3) and accumulate near the angle between two earthen dykes, forming the tailings



Figure 2. Open pit lead-zinc mine, Pine Point, N.W.T., 1971.

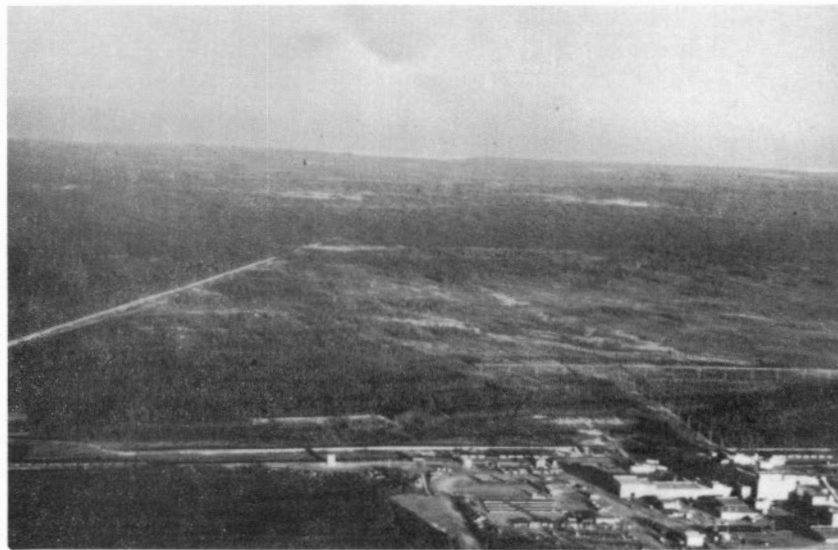


Figure 3. Pine Point Mine complex. Mill effluent is discharged from the "T" shaped trestle into the tailings pond and is partially retained by earthen dykes. Great Slave Lake appears in the background.

disposal area (Figure 4). Decanted effluent flows through four culverts, directly into the muskeg (Figure 5). Although the decant boxes are designed to permit their intake height to be increased, their efficiency is limited during periods of heavy runoff when much of the effluent flows around the short east-west dyke.



Figure 4. Accumulation of mill effluent at the angle between the two dykes, Pine Point, N.W.T., 1971. Two of the four decant culverts are visible. Stream flowing parallel to north-south dyke is pit water flow.



Figure 5. Muskeg between the mine tailings pond and Great Slave Lake, Pine Point, N.W.T., 1971.

## METHODS AND MATERIALS

## A. Sampling Area

Twenty-five sampling stations were established at various locations in and around the Pine Point property (Figure 6). Stations were selected to sample the proximate areas of:

- i) Tailings pond
- ii) Muskeg between the tailings pond and Great Slave Lake
- iii) South shore of Great Slave Lake from High Point to the Little Buffalo River (approximately 40 miles).

Twelve stations were located in Great Slave Lake, seven in streams or rivers flowing into the lake and six in bog lakes. Hay River was established as the base camp for the project. As travel to the outer limits of the study area involved approximately a 70 mile trip with few sheltered bays, a seaworthy, yet fast and maneuverable vessel was needed. For our purposes, a 17-foot OMC Catamaran powered by a 110 hp inboard-outboard motor proved most satisfactory.

## B. Field Procedures

1) Water sampling

Two litre surface water samples were collected at each of the established stations on a bi-monthly basis (Figure 7). These samples were submitted to the Water Quality Division of Environment Canada, Calgary, for detailed chemical analysis. Field tests were also carried out at each station with the aid of a Hach water analysis kit. Determinations of surface dissolved oxygen, alkalinity, pH and hardness were calculated. As

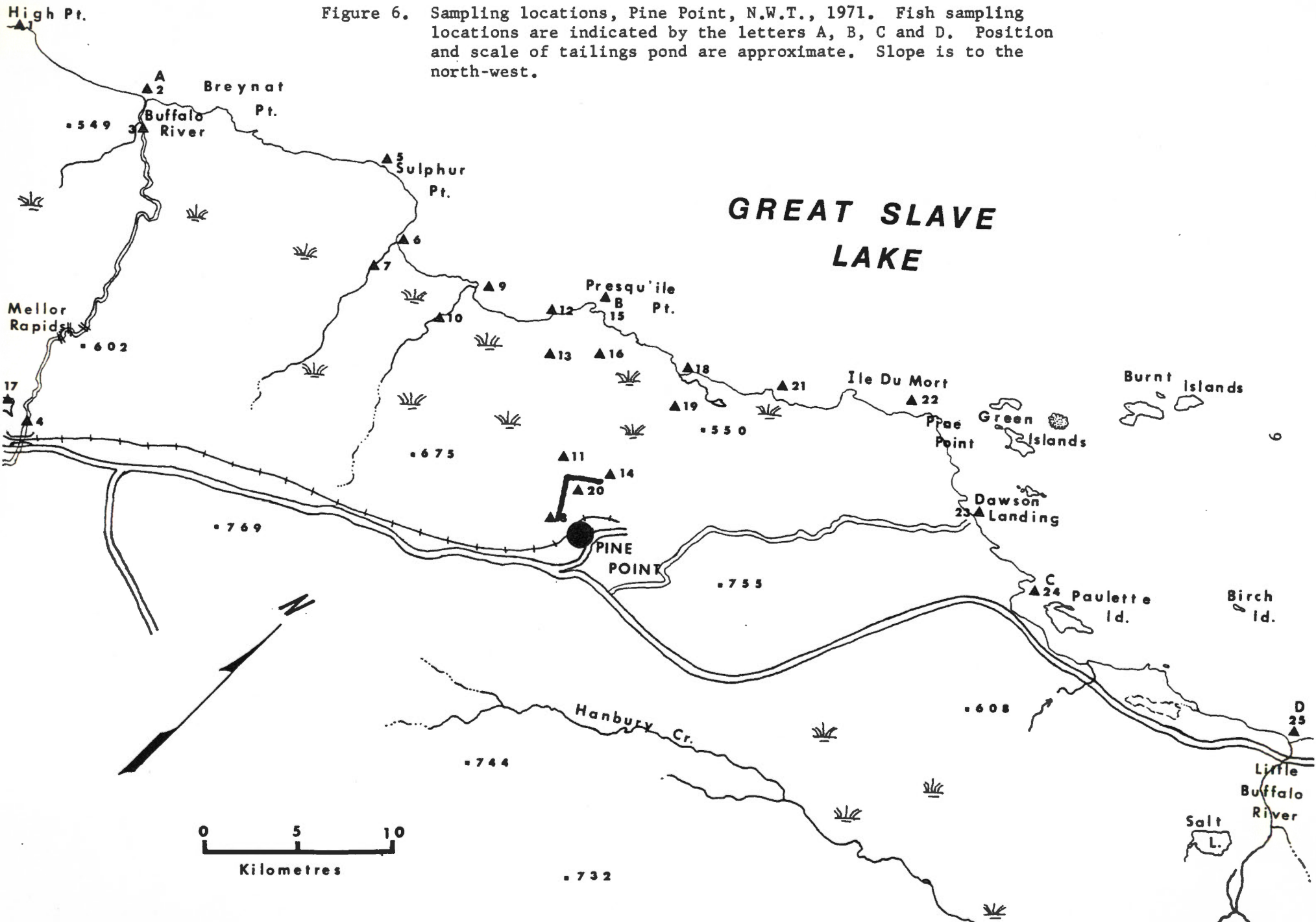


Figure 6. Sampling locations, Pine Point, N.W.T., 1971. Fish sampling locations are indicated by the letters A, B, C and D. Position and scale of tailings pond are approximate. Slope is to the north-west.

station depth was rarely more than eight feet, only surface temperatures were recorded. Turbidity was determined at each station by means of a Secchi disk.

An Isco automatic water sampler was used to collect 24 hour composite and hourly grab samples from decant culverts located in the tailings dyke. As each hourly grab sample contained 630 cc, four consecutive samples were combined to make up the required two litres.



Figure 7. Taking a water sample from the mine pit water, Pine Point, N.W.T.

## 2) Sediment sampling

Duplicate ten-ounce sediment samples were collected on a monthly basis from stations where it was readily obtainable. A six-inch Ekman dredge was used for sampling. One sample was forwarded for heavy metal

analysis to the Winnipeg Inspection lab of the Fisheries Service, while the duplicate sample was submitted to the Geology Department of the University of British Columbia for similar analysis.

Upon the request of mine officials, periodic sediment samples were shipped to the Cominco Analytical lab in Trail, B.C., for comparison purposes.



Figure 8. Collecting vegetation samples, Pine Point, 1971.

### 3) Vegetation sampling

Duplicate vegetation samples were collected from inland stations on a monthly basis. Enough sample was taken to fill an 8 x 18 inch plastic bag (Figure 8). It was then air dried for a period of up to a week, stored in paper bags and shipped to the Winnipeg Inspection lab of the Fisheries Service or the Department of Geology (U.B.C.) for heavy metal

analysis. Selected vegetation samples were also forwarded to the Cominco lab in Trail, British Columbia. The types of vegetation found most abundantly and consequently sampled most often were:

- 1) Cattail (Typha latifolia)
- 2) Willow (Salix spp.)
- 3) Labrador tea (Ledum groenlandicum)
- 4) Aquatic grasses (Graminae spp.)
- 5) Horsetail (Equisetaceae spp.)

As the vegetation samples from station 11 were markedly higher in heavy metal content, different plant segments were sampled late in the program to determine that portion of the plant which concentrates the greatest amount of the various elements. Three segments of cattail (Typha latifolia) were studied, i.e. roots, submergent stem, and the remainder of the plant above water.

#### 4) Invertebrate sampling

Invertebrate samples were collected from lake stations with the aid of a six-inch Ekman dredge. A Surber sampler was used at stream and muskeg stations. All invertebrate sampling was carried out on a monthly basis. The samples were placed in pails for later screening with stainless steel cloth of 40 meshes per inch.

#### 5) Fish sampling

Fish samples were collected three times over the summer in the proximity of four areas (Figure 6):

- A) Buffalo River
- B) Presquile Point

C) Dawson Landing

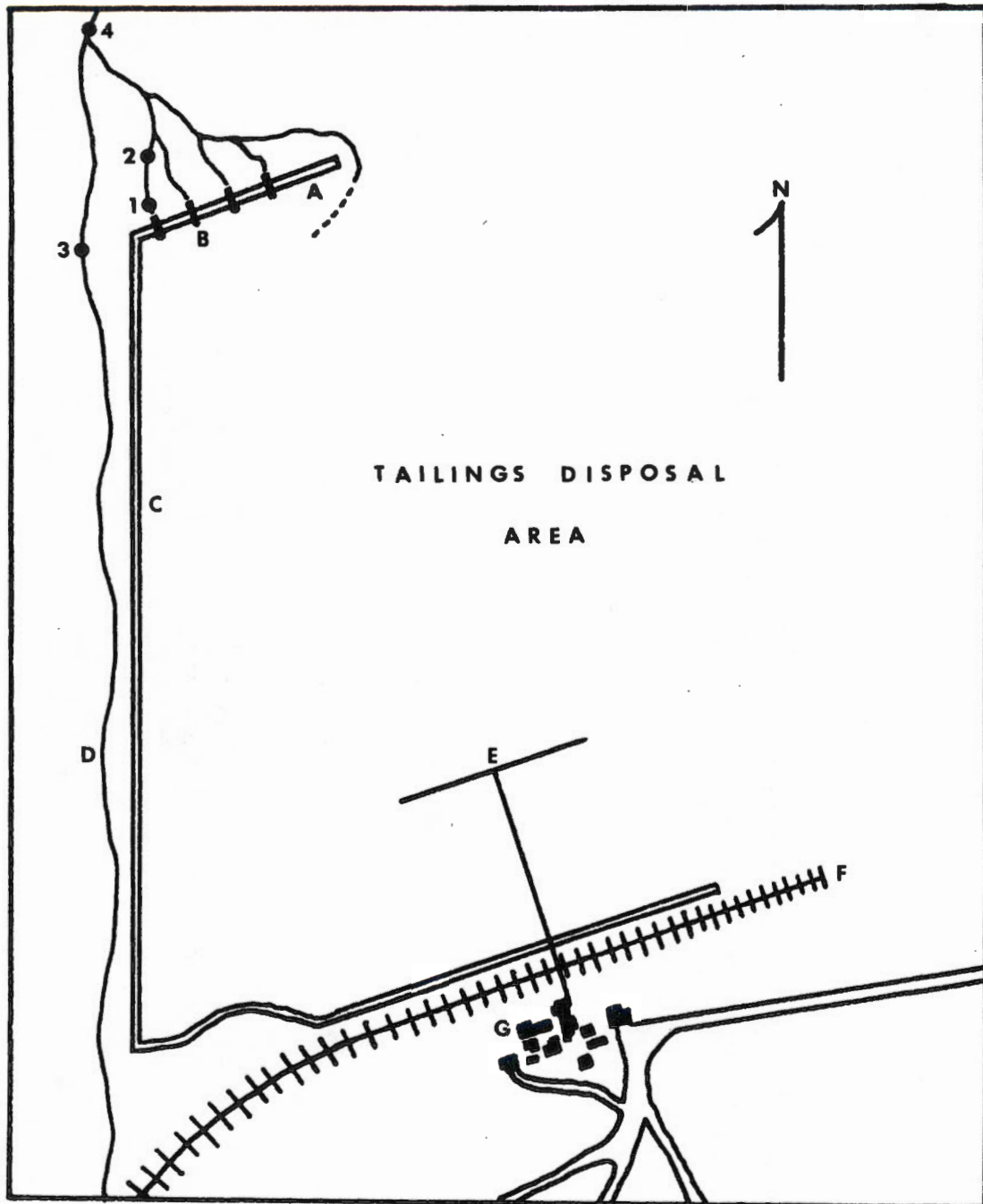
D) Little Buffalo River

Sampling was by means of 150 yard nylon gill net gangs, consisting of 25 yard sections of 1 1/2, 2, 3, 4, 5, 5 1/2 inch stretch mesh. Nets were set in the evening and pulled the next morning, approximating a 12-hour set. Captured fish were weighed (round weight), measured (fork length) and sexed. Scale and otolith samples were taken from each fish for later age determination.

Samples of selected fish species were collected from each net set. Species selected were those most readily captured in a given area and/or used for local consumption. The liver and one skinned fillet were taken from these sample fish, placed in whirl pac plastic bags, frozen and submitted to the Winnipeg Inspection lab of the Fisheries Service, or the Department of Geology, University of British Columbia for heavy metal analyses. Fish samples were also shipped to the Chemistry Department, University of Prince Edward Island for pesticide analyses. The Cominco Analytical lab in Trail, B.C., upon request, also received fish samples. Control samples were obtained from commercial operators fishing near the head of the Mackenzie River.

#### 6) Bioassay techniques

In mid-August, yellow walleye (Stizostedion vitreum vitreum) ranging from five to eight inches were seined from the Hay River and transported 60 miles to four test sites around the tailings area (Figure 9). Five fish were placed in a wire mesh collapsible holding cage at each test site and checked periodically until all specimens had died (Figure 10). Time of death, noticeable behavior changes, etc., were recorded with each visit.

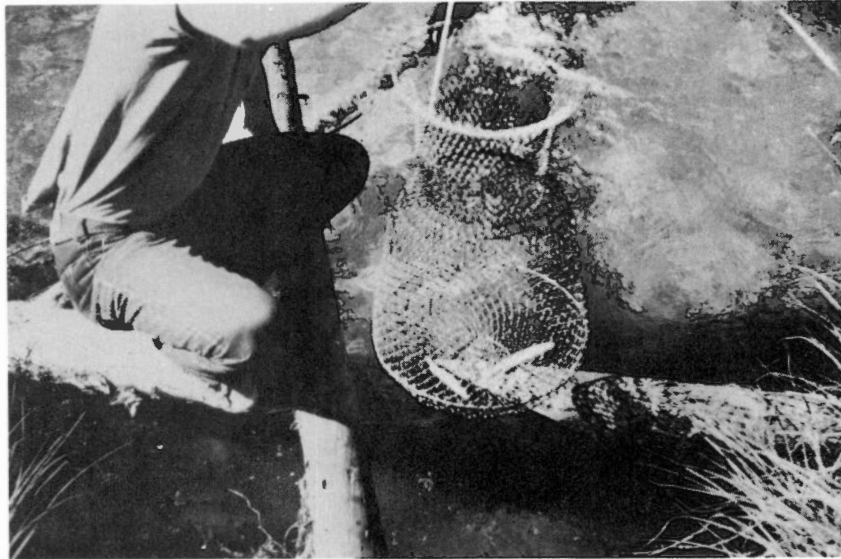


- |                              |                               |
|------------------------------|-------------------------------|
| A - East-west dyke           | E - Tailings disposal trestle |
| B - Tailings decant culverts | F - Railway line              |
| C - North-south dyke         | G - Mill complex              |
| D - Pit water flow           |                               |

Figure 9 . Test sites (1, 2, 3, 4) used for bioassays, Pine Point, N.W.T., 1971. Scale and flow patterns approximate.

A few brook trout fingerlings (Salvelinus fontinalis) were also used in the bioassay tests. These were seined from Polar Lake, approximately 30 miles from the test site.

Figure 10. Test apparatus used in bioassays, Pine Point, N.W.T.



### C. Lab Procedures

#### 1) Water analyses

Table 1 briefly outlines the methods used in determining the listed water chemistry parameters. More detailed descriptions can be found in Traversy (1971).

Table 1. Techniques used in the analysis of water samples collected from the area of Pine Point, N.W.T., 1971.

<u>Parameter</u>	<u>Method</u>
Turbidity	Hach turbidimeter
pH	Electrometric
Dissolved copper	Atomic absorption (direct)
Dissolved lead	Atomic absorption (direct)
Dissolved zinc	Atomic absorption (direct)
Dissolved sulphate	Titration with barium chloride
Specific conductance	Radiometer meter
Total alkalinity	Potentiometric titration
Total hardness	Titration with EDTA (EBT indicator)

2) Heavy metal and chlorinated hydrocarbon analyses

Most heavy metal analyses conducted on fish, sediment and vegetation samples were done by atomic absorption. Lead levels determined by the Geology Department, U.B.C., were done by dithizone colorimetry, while copper contents were checked by biquinoline colorimetry and zinc levels by dithizone titration. Samples were analysed for chlorinated hydrocarbons by gas chromatography.

## RESULTS

## A. Water Samples

Results obtained from the analysis of water samples collected from the sampling stations proved highly variable and with few apparent patterns. The closer the station was to the tailings area, the greater were the extremes encountered. The water chemistry data presented in Table 2 is considered to be representative of all of the locations sampled.

Levels of dissolved zinc, copper and lead found in samples from locations 1, 2, 3, and 4 were similar. Metal levels obtained from stations 5, 6, 7, 9, 10, 12, 13, 15, 16, 18, 19, 21, 22, 23, and 24 were also generally similar, and the zinc and copper levels at these locations were comparable to those found in the Buffalo River area. However, the concentrations of dissolved lead were generally slightly higher.

Stations 11, 20, and 14 showed the greatest extremes in the metal levels detected. Station 20 was located within the tailings pond itself, and 11 just downstream of the junction between the tailings and pit water flows. Station 14 was positioned at the end of the east-west dyke. The effluent flow at this location does not pass through the decant system. Station 8, located in the mine pit water flow, showed considerably lower levels of heavy metals than did the adjacent stations, although the readings for dissolved sulphate, specific conductance, total alkalinity and hardness were high compared to the lake stations. Efforts to monitor changes in water chemistry between these locations and the lake were thwarted by the terrain and the lack of suitable transportation into the area. Results

Table 2. Analysis results obtained from representative water samples collected from the Pine Point area, N.W.T., 1971.

Station	Date	Turbidity (J.T.U.)	pH	Dissolved Copper (ppm)	Dissolved Lead (ppm)	Dissolved Zinc (ppm)	Dissolved Sulphate	Specific Conduc- tance (micro- MHOS/cm)	Total Alkalinity (mg/l)	Total Hardness (mg/l)
3	9/6/71	53.0	7.8	0.002	0.008	0.001	55.2	284.0	60.8	96.6
	22/6/71	19.0	7.9	0.003	0.006	0.003	133.0	903.0	73.3	216.0
	8/7/71	8.6	7.6	0.002	0.006	0.003	52.0	401.0	76.1	127.0
	10/8/71	12.0	7.5	0.004	0.005	0.006	73.9	585.0	95.7	166.0
8	7/6/71	1.2	7.9	0.001	0.008	0.002	571.5	1440.0	280.0	866.0
	23/6/71	0.7	8.0	0.001	0.006	0.002	569.0	1462.0	257.0	854.0
	5/7/71	1.7	7.7	0.001	0.005	0.001	560.0	1430.0	193.0	770.0
	26/7/71	1.3	7.8	0.001	0.005	--	579.0	1470.0	187.0	778.0
	9/8/71	0.9	7.7	0.011	0.005	0.002	568.0	1460.0	234.0	811.0
	6/9/71	1.6	8.0	0.001	--	0.002	554.0	1510.0	156.0	743.0
9	9/6/71	2.8	8.0	0.001	0.008	0.001	63.2	276.0	81.4	115.0
	22/6/71	4.4	7.9	0.002	0.006	0.002	142.0	524.0	104.0	248.0
	8/7/71	11.0	7.7	0.002	0.006	--	45.4	293.0	86.2	125.0
	18/8/71	31.0	7.9	0.001	0.014	0.001	28.1	258.0	81.4	106.0
11	7/6/71	14.0	7.4	0.014	0.008	0.620	1927.0	3570.0	65.2	2187.0
	23/6/71	42.0	7.4	0.015	0.023	0.210	1653.0	3270.0	14.4	1950.0
	5/7/71	33.0	6.4	0.023	0.050	0.420	1704.0	3260.0	5.6	1884.0
	26/7/71	7.7	6.7	0.110	0.017	0.330	1688.0	3160.0	11.9	1839.0
	9/8/71	43.0	7.8	0.008	0.026	0.650	1142.0	7070.0	124.0	1345.0
	6/9/71	4.9	6.6	0.017	0.009	0.220	1697.0	3300.0	5.9	1909.0
14	1/4/71	16.0	7.5	0.041	0.042	0.220	2105.0	4430.0	109.0	2509
	20/4/71	180.0	7.0	0.016	0.050	0.240	1115.0	2225.0	17.2	1221.0
	7/6/71	60.0	7.1	0.002	0.270	--	1757.0	3400.0	39.7	2004.0
	23/6/71	15.0	7.4	0.002	0.390	0.110	2045.0	3890.0	205.0	2443.0
17	23/6/71	49.0	7.7	0.002	0.013	0.033	779.0	1790.0	184.0	1013.0
	9/8/71	1.8	8.2	0.006	0.006	0.004	30.9	330.0	140.0	177.0
	6/9/71	1.4	8.5	--	--	0.002	31.2	342.0	143.0	178.0

Table 2. Analysis results obtained from representative water samples collected from the Pine Point area, N.W.T., 1971.  
(Continued)

Station	Date	Turbidity (J.T.U.)	pH	Dissolved Copper (ppm)	Dissolved Lead (ppm)	Dissolved Zinc (ppm)	Dissolved Sulphate	Specific Conduc- tance (micro- MHOS/cm)	Total Alkalinity (mg/l)	Total Hardness (mg/l)
18	1/6/71	1.6	8.1	0.001	0.006	0.001	33.2	244.0	74.2	104.0
	21/6/71	8.4	8.1	0.001	0.006	0.001	69.4	364.0	87.0	157.0
	9/7/71	16.0	7.6	0.002	0.009	--	664.0	349.0	88.5	149.0
	18/8/71	0.6	8.5	0.001	0.014	0.001	849.0	1910.0	239.0	1123.0
20	7/6/71	2.7	6.6	0.041	0.230	0.940	2019.0	3660.0	19.0	2294.0
	23/6/71	--	7.6	0.010	0.100	0.290	1751.0	3280.0	26.9	2003.0
	5/7/71	48.0	6.8	0.087	0.012	0.240	1584.0	3140.0	13.6	1821.0
	26/7/71	9.3	6.7	0.110	0.040	0.250	1627.0	3190.0	6.0	1812.0
	9/8/71	4.2	8.2	0.020	0.062	0.410	634.0	1440.0	148.0	811.0
	6/9/71	19.0	7.1	0.022	0.041	0.160	1621.0	3255.0	22.5	1847.0
23	1/6/71	1.8	8.1	0.001	0.005	0.001	33.7	254.0	77.0	107.0
	21/6/71	7.2	8.1	0.001	0.005	0.001	37.9	289.0	83.3	118.0
	9/7/71	6.5	7.7	0.001	0.006	0.001	28.6	255.0	84.9	109.0
	18/8/71	46.0	7.9	0.002	0.014	0.001	24.7	245.0	82.0	104.0

obtained from the analysis of hourly grab samples of decant effluent indicate that no significant changes in the chemistry make-up of the effluent occurred over the 24-hour period.

No consistent seasonal patterns were detected. Highest readings probably coincide with periods of heavy flow, when large increases occur in the amount of suspended solids carried by effluent leaving the tailings area.

Relatively high levels of zinc, copper and lead were encountered at station 17 during the first sampling period. Station 17 was located in a muskeg pond and was used as a control, since information obtained from the mine indicated this to be a unmineralized area. It is possible that this initial sample may have been contaminated.

## B. Sediment Samples

Heavy metal contents found in sediment samples from the Pine Point area are presented as ppm dry weight in Table 3. Data from additional samples analysed by Cominco Limited are given in Appendix 1. Although the results obtained by Cominco appear similar to those from the present study, they have not been included in any of the calculations. Cadmium analyses were not attempted by the Cominco lab.

Mean levels determined for sample locations 3, 4, 7, 10, 17, 23 and 25 are relatively low and considered to be similar. Being fairly removed from the tailings area, it is probable that levels found at these locations are mostly natural in origin. However, there appeared to be significant increases in the heavy metal content of samples taken from locations 13 and 16 and especially from locations 18 and 19, indicating a substantial area of the muskeg is being contaminated by mine effluent.

When mean levels found at locations 8, 11, 14 and 20 are studied, it is apparent that large amounts of sediment are being deposited in the muskeg between the tailings area and the lake shore. Results from station 8 are generally less than those of the three adjacent stations since it was located in the mine pit water and does not receive any of the tailings flow.

The presence of cadmium in amounts as high as 22 ppm was unexpected. Cadmium levels found at stations remote from the mine were generally less than 0.5 ppm and were probably natural in origin. Greatest levels were encountered at those stations situated in the tailings flow. Cadmium often occurs as an impurity in lead-zinc ores, and forms less than 0.01% of the feed material at Pine Point.

Table 3. Heavy metal content (ppm dry weight) found in sediment samples collected from the area of Pine Point, N.W.T., 1971.

Station No.	Date/Mean	Pb	Cu	Zn	Cd
3	9/6/71	8.2	7.1	93.0	<0.5
	8/7/71	7.1	13.1	106.0	0.8
	10/8/71	3.6	--	90.0	<0.5
	$\bar{X}$	6.3	10.1	96.0	<0.6
4	3/6/71	2.9	7.1	48.0	<0.5
7	9/6/71	6.4	0.0	95.0	<0.5
	7/7/71	1.8	0.6	76.0	<0.5
	18/8/71	6.4	19.0	83.0	<0.5
	$\bar{X}$	4.9	6.5	84.0	<0.5
8	7/6/71	458.0	29.0	1900.0	3.3
	9/8/71	23.6	6.6	262.0	0.5
	27/9/71	--	3.0	312.0	1.0
	$\bar{X}$	240.8	12.9	824.0	1.6
10	9/6/71	2.9	10.7	55.0	<0.5
	9/7/71	1.4	10.7	46.0	<0.5
	18/8/71	3.6	12.0	76.0	<0.5
	$\bar{X}$	2.6	11.1	59.0	<0.5
11	7/6/71	4375.0	188.0	8600.0	15.8
	5/7/71	4250.0	188.0	7700.0	13.0
	9/8/71	4250.0	150.0	4800.0	9.7
	27/9/71	3125.0	250.0	7900.0	15.3
	$\bar{X}$	4000.0	194.0	7250.0	13.4
13	2/6/71	4.6	5.4	200.0	1.8
	7/7/71	18.9	14.3	200.0	1.0
	$\bar{X}$	11.7	9.8	200.0	1.4
14	7/6/71	2125.0	94.0	3600.0	7.1
	5/7/71	4000.0	219.0	8300.0	16.3
	27/9/71	4125.0	144.0	4700.0	9.7
	$\bar{X}$	3417.0	152.0	5533.0	11.0
16	2/6/71	0.5	35.0	321.0	2.1
	9/7/71	4.3	6.0	142.0	1.8
	18/8/71	4.3	8.3	72.0	<0.5
	$\bar{X}$	3.0	16.4	178.0	1.5
17	9/8/71	4.3	8.4	50.0	<0.5
18	18/8/71	400.0	94.0	1300.0	3.6

Table 3. Heavy metal content (ppm dry weight) found in sediment samples collected from the area of Pine Point, N.W.T., 1971. (Cont.)

Station No.	Date/Mean	Pb	Cu	Zn	Cd
19	7/6/71	36.4	54.0	1100.0	3.0
	9/7/71	35.0	55.0	1400.0	3.8
	$\bar{X}$	35.7	49.5	1250.0	3.4
20	7/6/71	6250.0	150.0	6800.0	14.3
	5/7/71	1150.0	188.0	6300.0	12.2
	9/8/71	250.0	238.0	7900.0	15.1
	27/9/71	5720.0	175.0	11,000.0	22.4
	$\bar{X}$	3342.0	187.0	8000.0	16.0
23	8/7/71	3.2	7.1	45.0	<0.5
25	25/8/71	2.5	6.0	46.0	<0.5

Attempts at graphing the results chronologically yielded highly irregular results. Assuming the sampling methods and locations were consistent, it is probable that variations are the result of either an increased discharge from the mill or a heavy runoff resulting from the spring thaw or periods of precipitation.

### C. Vegetation Samples

Results from the heavy metal analyses conducted on vegetation samples are presented in Table 4. Results from four additional samples analysed by Cominco Limited, Trail, B.C. are presented in Appendix 2. Lead levels determined by Cominco were frequently slightly higher than those presented in Table 4.

Most of the levels presented probably represent normal amounts of each element concentrated by the plants. Very little cadmium was apparently absorbed as it is probably not an important element in the physiology of the plants sampled.

At station 11, several samples of cattail (Typha latifolia) were collected in an effort to determine which plant sections concentrate the greatest amounts of the various metals. Two root samples and three stem samples were collected August 9, 1971. Root samples contained greater mean levels of all elements (Pb = 120.5 ppm; Cu = 37.5 ppm; Zn = 875.0 ppm; Cd = 0.3 ppm) than did the stem sections (Pb = 29.0 ppm; Cu = 8.5 ppm; Zn = 193.6 ppm; Cd = 0.0 ppm).

Station 11 undoubtedly possessed greater amounts of these elements than were needed for good plant growth. Although efforts were made to prevent sample contamination, it is still a possibility and could greatly bias the means obtained from such a small sample size.

Table 4. Heavy metal content (ppm dry weight) found in vegetation samples collected from the area of Pine Point, N.W.T., 1971.

Station	Date	Plant Spp.	Plant Section	Pb	Cu	Zn	Cd
1	9/6/71	Typha Latifolia	Mixed	0.0	2.5	17.5	5.5
3	9/6/71	Typha Latifolia	Mixed	4.3	44.4	47.5	0.0
	7/7/71	Typha Latifolia	Mixed	0.7	4.1	38.0	0.0
	10/8/71	Equisetacea Spp.	Stems	9.0	3.6	23.0	0.0
7	9/6/71	Graminae Spp.	Mixed	0.0	3.1	28.5	2.3
	8/7/71	Graminae Spp.	Mixed	0.0	3.8	22.5	0.0
10	9/6/71	Graminae Spp.	Mixed	0.0	1.0	16.0	0.0
	7/7/71	Graminae Spp.	Mixed	0.0	0.9	15.0	0.0
	18/8/71	Equisetacae Spp.	Stems	5.0	2.4	17.0	0.0
11	9/6/71	Typha Latifolia	Stems*	218.0	34.7	--	0.6
	9/8/71	Typha Latifolia	Stems	43.0	11.0	75.0	0.0
	9/8/71	Typha Latifolia	Roots	202.0	14.0	150.0	0.6
	9/8/71	Typha Latifolia	Stems*	26.0	9.6	106.0	0.0
	9/8/71	Typha Latifolia	Stems**	18.0	4.8	100.0	0.0
	9/8/71	Typha Latifolia	Roots (Nodes)	39.0	61.0	1600.0	0.0
	15/10/71	Typha Latifolia	Stems**	8.0	6.0	26.0	0.0
	15/10/71	Typha Latifolia	Stems (Submerged)	16.0	2.4	36.0	0.0
	15/10/71	Typha Latifolia	Roots (Runners)	10.0	5.2	12.0	0.0
	15/10/71	Typha Latifolia	Roots (Nodes)	33.0	24.0	205.0	1.8

Table 4 continued.

Station	Date	Plant Spp.	Plant Section	Pb	Cu	Zn	Cd
13	2/6/71	Graminae Spp.	Mixed	0.0	3.8	37.0	0.0
	7/7/71	Graminae Spp.	Mixed	0.7	4.3	28.5	0.0
16	2/6/71	Ledum Groenlandicum	Mixed	0.7	1.7	28.5	0.0
	9/7/71	Salix Spp.	Mixed	0.0	0.8	68.0	0.0
17	9/8/71	Salix Spp.	Stems	8.0	2.4	42.0	0.0
	9/8/71	Salix Spp.	Leaves	13.0	3.0	32.0	0.0
18	18/8/81	Ledum Groenlandicum	Stems	19.0	6.0	53.0	0.0
	18/8/71	Ledum Groenlandicum	Leaves	6.0	4.2	28.0	0.0
25	?	Typha Latifolia	Roots	3.6	2.8	8.0	0.0
	?	Typha Latifolia	Stems	8.0	3.6	8.0	0.0

\* Sample taken from highest part of submergent stem.

\*\* Sample taken from portion of submergent stem just above the primary root nodule.

#### D. Invertebrate Samples

In general, a stream may be considered as a clean water stream when the non-tolerant invertebrate species represent more than 50% of the population (Ingram, Mackenthun and Bartsch, 1966). All stations sampled in Great Slave Lake or on streams flowing toward the lake fall into this clean water category. Major families found were Gammaridea, Chironomidae, Talitridae and Simuliidae.

The interesting phenomenon concerns stations 8, 11, 14 and 20 in the immediate vicinity of the tailings area. Benthos did not exist at any of these locations in June, July, August or September. As these months are considered to be critical months for benthic fauna, i.e. reproduction, it can be concluded that the physical and/or chemical constituents of these stations prevent the growth of a benthic fauna population at any time of the year.

## E. Fish Samples

Mean heavy metal concentrations found in fish liver and muscle samples are presented in Tables 5 and 6 respectively. Results obtained by the Cominco lab from similar samples are presented in Appendix 3. They were not included in the following discussion.

Since two separate laboratories were involved in the analyses, Student "t" tests were made to compare the mean zinc and copper concentrations reported by the labs. Unfortunately, there was insufficient data to permit comparisons for all of the fish species sampled. At the 95% confidence level, no significant difference was found between lab means for humpback whitefish (Coregonus clupeaformis) livers (t values: Zn = 1.735, 10 df; Cu = 1.077, 10 df), or for northern pike (Esox lucius) livers (t values: Zn = 1.022, 4 df; Cu = 1.160, 4 df). Significant differences were found between the zinc and copper means determined for yellow walleye liver and muscle samples. However, since small samples were often obtained from some areas or species, the analyses results from the two labs have been combined in all cases.

Analysis results for individual contaminants are presented below.

### Zinc

For the species examined, northern pike livers taken from the combined sampling areas contained the greatest concentrations of zinc (30.97 ppm; N = 55). Burbot (Lota lota) showed the next highest level (29.00; N = 1), followed by humpback whitefish (28.87 ppm; N = 37), inconnu (Stenodus leucichthys nelma) (28.10 ppm; N = 13), white sucker (Catostomus commersoni) (20.00 ppm; N = 1) and yellow walleye (15.32 ppm; N = 24).

Table 5. Mean concentrations (in ppm wet weight) of zinc, copper, cadmium, lead, mercury, nickel, iron and manganese detected in the liver tissues of fish collected from Pine Point, N.W.T., 1971.

Species	S.L.	N	Zn	N	Cu	N	Cd	N	Pb	N	Hg	N	Ni	N	Fe	N	Mn
Humpback whitefish	A	13	30.65	13	13.76	9	0.20	4	0.41	-	-	8	0.36	1	41.00	9	1.41
	B	2	43.50	2	32.50	2	0.10	-	-	-	-	-	-	2	63.50	2	1.80
	C	1	32.00	1	7.20	1	0.20	-	-	-	-	-	-	1	55.00	1	2.20
	D	21	26.22	21	14.65	16	0.11	3	0.15	-	-	16	0.28	-	-	16	1.31
Northern pike	A	8	22.79	8	3.84	5	0.09	4	0.13	-	-	4	0.08	-	-	4	1.10
	B	14	35.74	14	4.32	1	0.20	10	0.53	-	-	-	-	1	64.00	1	0.60
	C	1	29.00	1	5.80	1	0.20	-	-	-	-	-	-	1	82.00	1	0.70
	D	32	30.99	32	7.80	23	0.08	14	0.14	-	-	4	0.22	2	14.30	14	0.99
Yellow walleye	A	20	14.68	20	1.21	12	0.13	7	0.21	-	-	12	0.21	-	-	12	1.06
	B	1	16.10	1	0.77	-	-	-	-	-	-	-	-	-	-	-	-
	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	3	19.30	3	2.60	3	0.37	-	-	-	-	-	-	-	-	3	1.60
Inconnu	A	10	26.64	8	21.26	7	0.16	3	0.08	-	-	1	0.10	5	84.20	5	1.50
	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	3	33.00	3	29.60	3	0.10	-	-	-	-	-	-	3	51.67	3	1.73
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White sucker	A	1	20.00	1	9.40	1	0.20	-	-	-	-	-	-	1	89.00	1	1.00
	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burbot	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	1	29.00	1	16.00	1	0.20	-	-	-	-	1	0.10	-	-	1	1.00

S.L. = Sample Location

Table 6. Mean concentrations (in ppm wet weight) of zinc, copper, cadmium, lead, mercury, nickel, iron and manganese detected in the muscle tissues of fish collected from Pine Point, N.W.T., 1971.

Species	S.L.	N	Zn	N	Cu	N	Cd	N	Pb	N	Hg	N	Ni	N	Fe	N	Mn
Humpback whitefish	A	8	3.89	8	0.30	3	0.03	5	0.06	3	0.13	1	0.00	1	35.00	3	0.57
	B	2	6.25	2	0.56	1	0.00	1	0.10	-	-	-	-	1	46.00	1	0.60
	C	7	4.34	6	0.54	7	0.03	2	0.10	-	-	-	-	-	-	5	0.28
	D	16	2.64	16	0.44	-	-	10	0.11	4	0.06	11	0.07	-	-	11	0.26
Northern pike	A	11	5.98	11	0.56	8	0.12	1	0.02	1	0.09	1	0.00	1	34.00	10	0.33
	B	5	3.71	5	0.26	1	0.00	4	0.17	3	0.15	-	-	1	13.00	1	0.20
	C	4	6.05	4	0.82	3	0.06	-	-	-	-	-	-	1	21.00	4	0.25
	D	29	6.26	27	0.55	18	0.04	10	0.20	2	0.30	1	0.20	8	21.62	20	0.38
Yellow walleye	A	14	4.33	14	0.57	8	0.12	6	0.14	2	0.16	2	0.10	-	-	10	0.21
	B	1	1.68	1	0.13	-	-	1	0.05	-	-	-	-	-	-	-	-
	C	1	3.90	1	0.70	1	0.12	-	-	-	-	-	-	-	-	1	0.20
	D	6	4.92	6	0.52	3	0.00	3	0.16	-	-	-	-	3	30.67	3	0.33
Inconnu	A	11	4.14	11	0.83	8	0.08	1	0.10	-	-	-	-	3	24.67	10	0.17
	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	1	13.00	1	0.50	1	0.10	-	-	-	-	-	-	-	-	1	0.50
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
White sucker	A	10	10.09	10	0.73	9	0.10	2	0.10	-	-	-	-	1	19.00	8	0.45
	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Burbot	A	1	6.50	1	1.00	1	0.23	-	-	-	-	-	-	-	-	1	0.40
	B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

S.L. = Sample Location

Samples of muscle tissue from white suckers had the highest zinc levels (10.09 ppm; N = 10), followed in order by burbot (6.50 ppm; N = 1), northern pike (5.92 ppm; N = 49), inconnu (4.88 ppm; N = 12), yellow walleye (4.35 ppm; N = 22) and humpback whitefish (3.52 ppm; N = 33). In Figure 11, the zinc levels found in muscle and liver tissues from the major species are plotted against fish weight. Although it appears that a linear relationship could exist for some species, it was not the proportionate one expected. Attempts to determine seasonal changes in zinc concentrations of northern pike and humpback whitefish livers failed to produce any consistent patterns. However, there did appear to be a significant variation with sampling location. Greater concentrations of zinc were found in the livers of humpback whitefish (43.50 ppm; N = 2) and northern pike (35.74 ppm; N = 14) from location B, adjacent to the mine, than were found in any of the other sampling areas (Figure 12). Yellow walleye showed very little increase.

A similar trend was noted in humpback whitefish muscle samples. However, the muscle concentrations found in northern pike and yellow walleye from location B were less than those from the other three areas. Significant patterns were not noted for the remaining species because of small sample sizes.

#### Copper:

Of the species examined, inconnu contained the greatest concentrations of copper in liver tissue (23.55 ppm; N = 11). Following in order were burbot (16.0 ppm; N = 1), humpback whitefish (15.10 ppm; N = 37), white sucker (9.4 ppm; N = 1), northern pike (6.31 ppm; N = 55) and yellow walleye (1.37 ppm; N = 24).

Mean concentrations of copper recovered from muscle

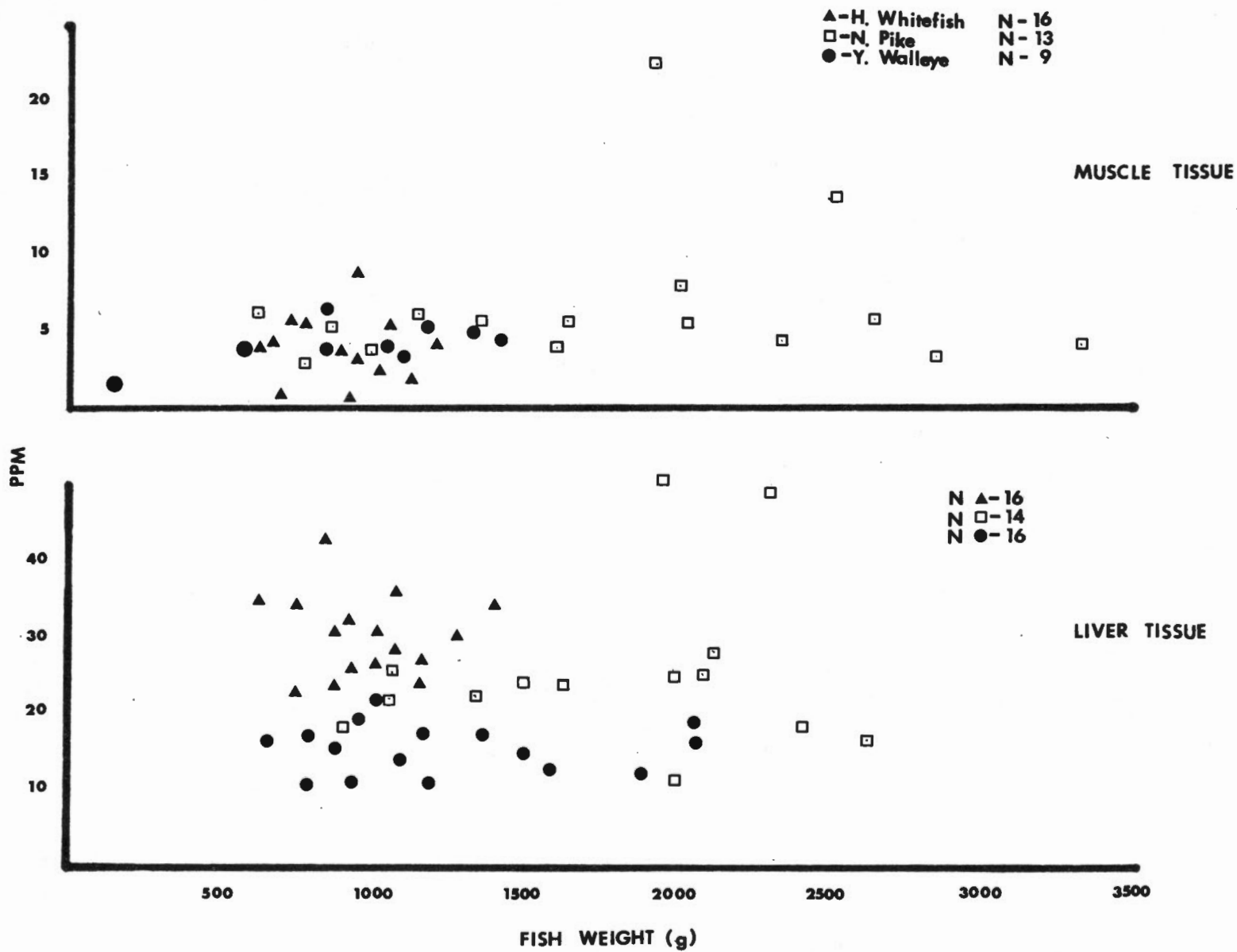
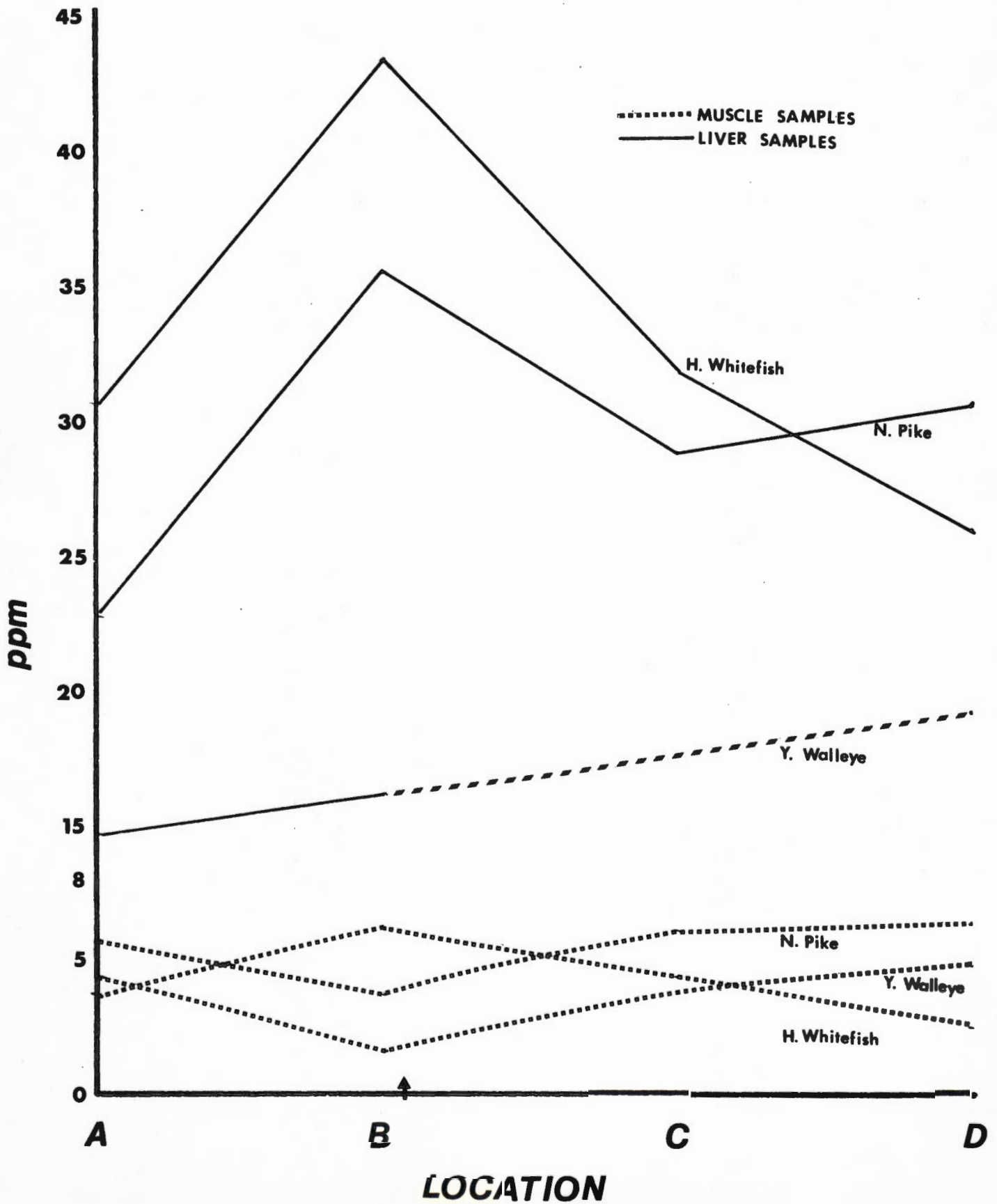


Figure 11. Zinc concentrations found in fish muscle and liver samples taken from the major species encountered at Pine Point, N.W.T., 1971.

Figure 12. Mean concentrations of zinc (ppm wet weight) determined from fish samples collected from four sampling locations, Pine Point, N.W.T., 1971. Arrow indicates approximate location of mine site in relation to the sampling areas.



samples were, in descending order, burbot (1.00 ppm; N = 1), white sucker (0.73 ppm; N = 10), inconnu (0.64 ppm; N = 12), northern pike (0.55 ppm; N = 47), yellow walleye (0.54 ppm; N = 22) and humpback whitefish (0.43 ppm; N = 32).

As with zinc, no proportionate relationships were found when copper concentrations were plotted against fish weight (Figure 13), nor were any seasonal changes in the copper levels of liver samples noted. When plotted by location, however, (Figure 14) the mean concentrations of copper found in the liver tissue of humpback whitefish increased sharply for fish taken in the proximity of the mine. Considerable variation resulted in the results obtained from northern pike and yellow walleye, and from muscle samples from all three species. Significant patterns were not noted for the remaining species because of small sample sizes.

#### Lead

Humpback whitefish livers contained the greatest mean amount of lead (0.30 ppm; N = 7), followed by northern pike (0.28 ppm; N = 28), yellow walleye (0.21 ppm; N = 7) and inconnu (0.08 ppm; N = 3). Northern pike appeared to have the highest concentration of lead in muscle tissue (0.18 ppm; N = 15) followed by yellow walleye (0.14 ppm; N = 2). Humpback whitefish, inconnu and white sucker all contained 0.10 ppm lead (N = 18, 1 and 2 respectively).

No significant trends were noted in the levels found in fish samples. Characteristics of the lead ion are such that only small amounts are usually concentrated in the body tissues of most fish species. Large amounts of lead compounds can act on the gill tissues of fish to cause clogging and suffocation. If such conditions did occur, most species would probably avoid the area.

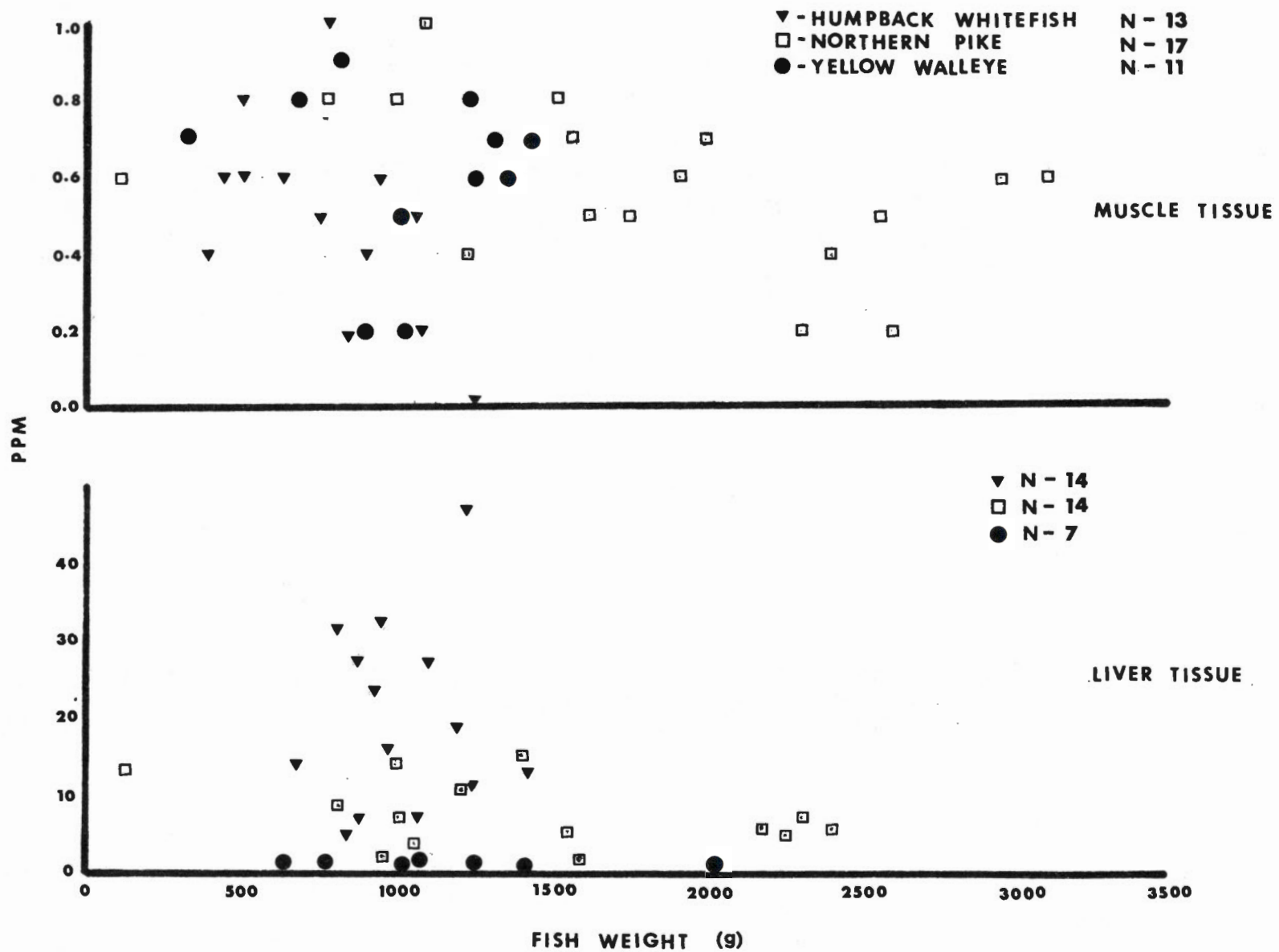
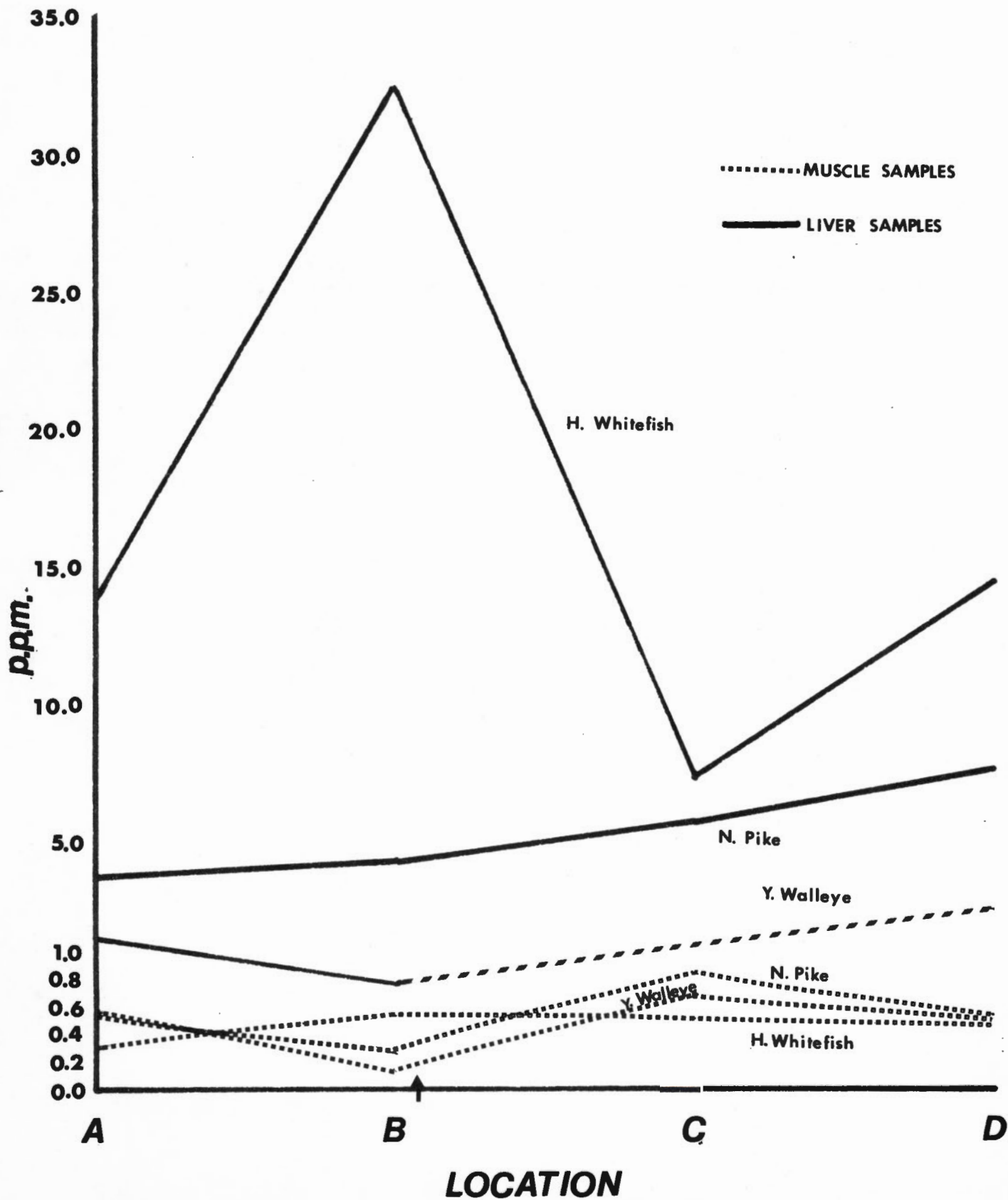


Figure 13. Copper concentrations found in fish muscle and liver samples taken from the major species encountered at Pine Point, N.W.T., 1971.

Figure 14. Mean concentrations of copper (ppm wet weight) determined from fish samples collected from four sampling locations, Pine Point, N.W.T., 1971. Arrow indicates approximate location of mine site in relation to the sampling areas.



Cadmium, Mercury, Nickel, Iron and Manganese

Mean levels of cadmium, mercury, nickel, iron and manganese found in the two tissue types are presented in Tables 5 and 6. No consistent patterns were noted. Small amounts of these elements occur in ores processed at Pine Point, but not in sufficient amounts to warrant extraction. Since they are passed off in the tailings, a portion of these metals are deposited in the muskeg and in the waters of Great Slave Lake. Their affects to the fish resources of the area has not been determined.

Chlorinated Hydrocarbons

All of the fish selected for chlorinated hydrocarbon analysis were humpback whitefish. Results of the analyses are presented in Table 7.

Table 7. Concentrations of chlorinated hydrocarbons recovered from whole fish samples collected from the area of Pine Point, N.W.T., 1971<sup>1</sup>.

Species	Fish Weight (g)	o,p'-DDT <sup>2</sup> (ppm)	o,p'-DDE (ppm)
Humpback whitefish	800	L0.01 <sup>3</sup>	L0.01
Humpback whitefish	750	L0.01	0.05
Humpback whitefish	1050	L0.01	0.03
Humpback whitefish	950	L0.01	0.07
Humpback whitefish	1000	L0.01	L0.01
Humpback whitefish	850	L0.01	0.05
Humpback whitefish	1060	L0.01	L0.01

<sup>1</sup>Analysis of three humpback whitefish samples by Fisheries Research Board, Winnipeg, yielded only trace amounts of DDE, Dieldrin and DDT. None of these was detected by the Chemistry Department, University of Prince Edward Island.

<sup>2</sup>DDE is thought to be a metabolite of DDT in a biological environment. o,p'-DDT is a 15-20% constituent of technical (p,p' ) DDT.

<sup>3</sup>L equals "less than".

The levels of chlorinated hydrocarbons detected were not considered to be exceptional.

## F. Bioassay Tests

Although yellow walleye were the most abundant local species seined, obtaining test fish of equal size and condition was difficult. Efforts were made to minimize stress during handling, but this was undoubtedly an adverse factor. The most significant problem encountered was that of maintaining adequate control and observation during the experiments.

The reliability of results obtained from the bioassays must, therefore, be interpreted with caution, and the tests considered only as token experiments. A more detailed experiment is being designed and will be initiated in the summer of 1972. Results of this experiment will be added to the present report when they are made available.

A visit to the test area was made twelve hours after the start of the experiment, with no fish mortality in any test site. Strong current (approximately 3 ft/sec) at site 3 had left the fish in an obvious weakened condition. The 48 hour observation yielded 2 fish dead at location 2 and all fish dead at location 3. An 11 day observation yielded similar results with the exception of station 4, where one specimen had died. A visit 15 days later produced similar findings. Brook trout fingerlings were then subjected to the decant water at station 1. Two days later, all test fish had died except one in site 4. No settling had occurred in the tailings pond and effluent flowed freely through the decant culverts, contaminating the remaining test sites. Field autopsy indicated suffocation as a principal cause of death as the gill rakers, filaments, etc. were heavily clogged with the silty effluent. All brook trout had died by day 5 of their test experiment.

## DISCUSSION

Results obtained from the analysis of mud, invertebrate and vegetation samples indicate that a large area of the muskeg is being contaminated by mine tailings. However, the majority of zinc, copper and cadmium results obtained from water samples taken near or from Great Slave Lake, fall within the safe range, as interpreted by the American Fisheries Society Ad Hoc Committee on Heavy Metal Contamination (Table 8) (Lucas, 1971).

Table 8. Lethal and safe concentrations (in mg/l) of some heavy metals for aquatic life.<sup>1</sup>

<u>Metal</u>	<u>Lethal</u>	<u>Safe</u>
Zinc	0.01 - 10.0	0.010 - 0.050
Copper	0.01 - 5.0	0.005 - 0.025
Mercury	0.005 - 0.5	
Lead	0.01 - 50.0	
Cadmium	0.003 - 10.0	0.001 - 0.03

<sup>1</sup>From report of the American Fisheries Society Ad Hoc Committee on Heavy Metal Contamination, as recorded by Lucas, 1971.

Fluctuations in effluent discharge probably raise these levels into the lethal range. Although some fish will avoid such conditions, resident species may be drastically affected. Sprague (1964) determined the incipient lethal level<sup>2</sup> of young Atlantic salmon (Salmo salar L.) to be 48 µg/l (0.048 mg/l) of copper and 600 µg/l (0.6 mg/l) of zinc.

<sup>2</sup> Incipient lethal level (ILL) is considered to be that level of the lethal identity beyond which the organism can no longer survive for an indefinite period of time.

It was also found that fish died twice as fast in solutions containing both copper and zinc than would occur if the two metals were simply additive in their lethal action.

Sprague (1965) also determined that young salmon populations were severely depressed every year in the heavy metal polluted Miramichi River (New Brunswick) and that low supply of eggs and poor survival rates were both contributory causes.

With the exception of lead, mean levels of heavy metals found in fish samples were generally comparable with those found in control samples taken near the head of the Mackenzie River (Table 9). Lead levels found in muscle samples from the south shore were higher than those of the controls. Fish samples collected by Hatfield et al (1971) yielded results similar to the controls (Table 10).

Table 10. Mean concentrations of heavy metals (ppm wet weight) recovered from fish samples collected from the vicinity of Fort Simpson, Norman Wells and Arctic Red River, Mackenzie River Valley, 1971.<sup>1</sup>

Species	Liver Tissue				Muscle Tissue		
	Zn	Cu	Cd	Pb	Zn	Cu	Hg
Humpback whitefish	30.00	16.65	0.27	--	5.34	0.34	0.14
Broad whitefish	32.79	20.10	0.20	0.00	--	--	--
Arctic cisco	30.43	3.87	--	0.00	8.70	0.57	--
Longnose sucker	30.30	3.87	0.38	0.10	7.44	0.37	0.08
Inconnu	26.27	11.45	--	0.21	--	--	--
Northern pike	28.64	5.42	--	--	6.81	--	0.09

<sup>1</sup>Original data from Hatfield et al, 1971.

However, on the basis of the few samples collected, it appears that fish from Great Slave Lake caught nearest the mine complex have concentrated greater amounts of the heavy metals analysed for than did fish from the other areas sampled. From a study of British Columbia trout, Warren et al (1971) hypothesized that fish liver tissues containing more

Table 9. Concentrations of heavy metals (ppm wet weight) detected in muscle samples of fish collected near the head of the Mackenzie River, 1971.

Tissue	Species	Location	Pb	Cu	Zn	Cd	Hg
Muscle	Northern Pike	Pt. Desmarais	0.0	0.25	5.3	0.0	0.19
Muscle	Northern Pike	Pt. Desmarais	0.0	0.15	3.9	0.0	0.14
Muscle	Northern Pike	Pt. Desmarais	0.0	0.40	4.0	0.0	0.22
Muscle	Humpback Whitefish	Pt. Desmarais	0.0	0.30	2.9	0.0	0.07
Muscle	Humpback Whitefish	Pt. Desmarais	0.0	0.40	3.3	0.0	0.04
Muscle	Humpback Whitefish	Pt. Desmarais	0.0	0.30	3.0	0.0	0.04
Muscle	Humpback Whitefish	Pt. Desmarais	0.0	0.25	2.6	0.0	0.07
Muscle	Inconnu	Pt. Desmarais	0.0	0.45	4.0	0.0	0.06
Muscle	Inconnu	Pt. DeRoche	0.0	0.25	4.9	0.09	0.05
Muscle	Inconnu	Pt. DeRoche	0.0	0.30	3.5	0.0	0.06
Muscle	Inconnu	Pt. DeRoche	0.0	0.30	3.2	0.0	0.06
Liver	Inconnu	Pt. Desmarais		7.0	18.0	0.09	
Liver	Inconnu	Pt. DeRoche		7.9	19.0	0.11	
Liver	Inconnu	Pt. DeRoche		11.0	14.0	0.06	
Liver	Inconnu	Pt. DeRoche		9.7	29.0	0.01	
Liver	Northern Pike	Pt. Desmarais		3.0	29.0	0.07	
Liver	Northern Pike	Pt. Desmarais		1.0	17.0	0.04	
Liver	Northern Pike	Pt. Desmarais		2.6	24.0	0.11	
Liver	Northern Pike	Pt. Desmarais		3.2	13.0	0.03	
Liver	Humpback Whitefish	Pt. Desmarais		6.9	30.0	0.24	
Liver	Humpback Whitefish	Pt. Desmarais		14.0	44.0	0.26	
Liver	Humpback Whitefish	Pt. Desmarais		23.0	34.0	0.15	
Liver	Humpback Whitefish	Pt. Desmarais		12.0	48.0	0.22	

than 40 ppm zinc, 80 ppm copper or 1.2 ppm lead, could be considered exceptional. At least six of the fish livers from location B exceeded 40 ppm zinc. Should the levels of heavy metal contamination of fish increase, the effects could be lethal or at least could render the resource unfit for human consumption.

## CONCLUSIONS AND RECOMMENDATIONS

The data presented in this report indicate that sub-lethal amounts of heavy metals are entering Great Slave Lake via the Pine Point tailings system. Further investigations, including more accurate bioassays of the tailings effluent and an extended monitoring program, are strongly recommended. Surges of heavy metal pollution resulting from the spring runoff or freshets are not only capable of killing fish directly, but also be some secondary ailment or stress, triggered by or added onto the stress of sub-lethal metal pollution (Sprague *et al.*, 1968).

The tailings system employed at Pine Point is considered to be only partially effective at best. One or more of the four decant boxes have frequently been totally inoperative due to sediment clogging (Figures 15 and 16). Increased flow resulting either from freshets or fluctuations in mill production limit the effectiveness of the decant boxes and increase the sediment load of the decant effluent (Figures 17 and 18).

The effectiveness of the existing tailings disposal system is further limited by the heavy deposition of solids at the angle of the two dykes. Winter ice conditions have resulted in the tailings level coming dangerously close to the top level of the dykes. During the period of spring runoff, as much as 50% of the outlet discharge spreads around the eastern end of the east-west dyke, without passing through the decant system. The water outlet discharge during this period is estimated to  $30 \times 10^6$  gallons per day (Berube and Frenette, 1971) (Figure 19).

It is obvious that the life expectancy of the existing Pine Point tailings system is short. It is, therefore, imperative that work begin

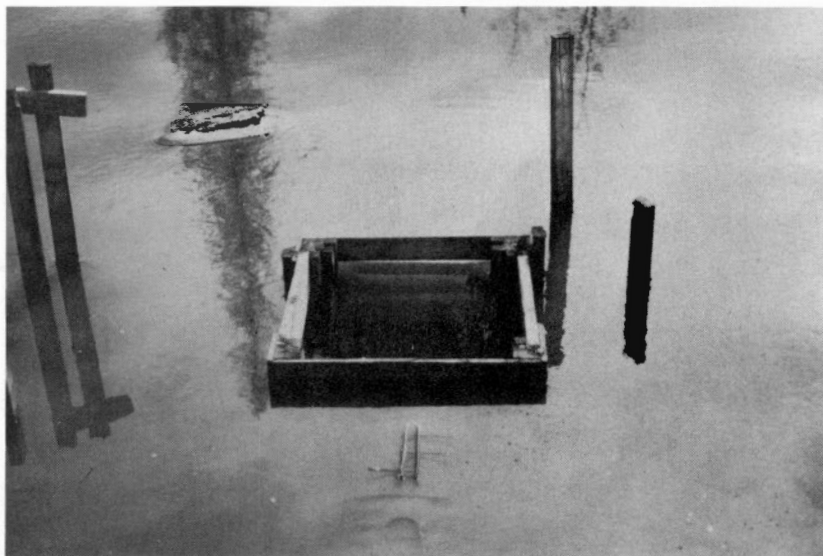


Figure 15. Tailings decant box under normal operating conditions, Pine Point, N.W.T., 1971.

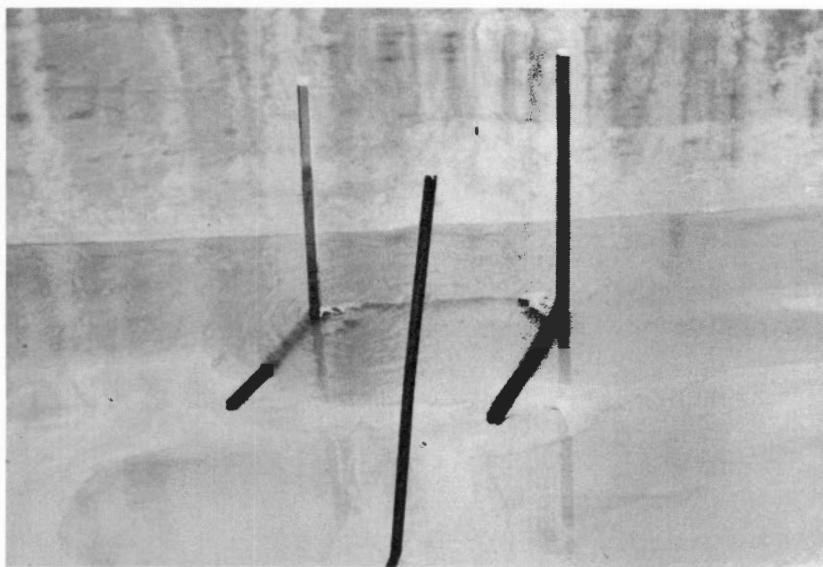


Figure 16. Tailings decant box, inoperative due to sediment clogging, Pine Point, N.W.T., 1971.

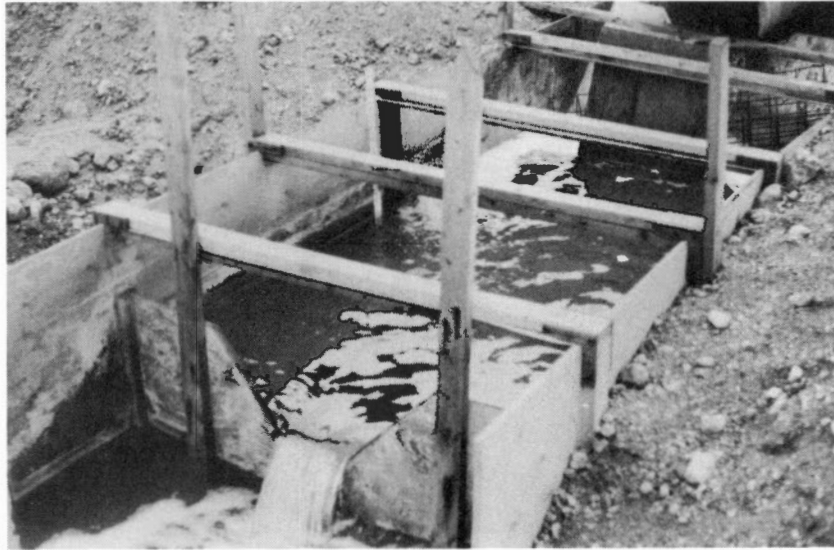


Figure 17. Relatively clean effluent emerging from decant culvert under normal operating conditions, Pine Point, N.W.T., 1971.

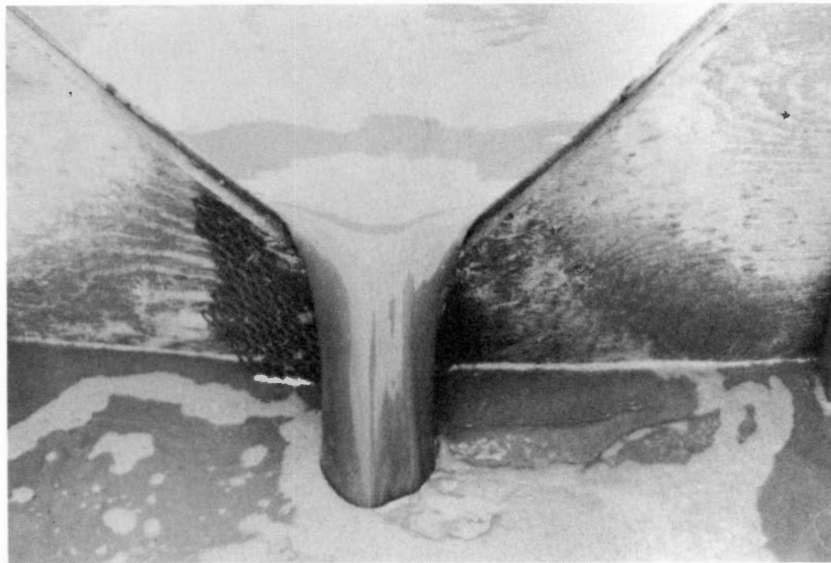


Figure 18. Increased sediment load in decant effluent resulting after a freshet, Pine Point, N.W.T., 1971.



Figure 19. Tailings flow around the end of the east-west dyke, Pine Point, N.W.T., 1971.

immediately on the installation of an improved disposal system. Recommendations for such a system are listed below in order of preference:

1. Complete in mill recycling of all effluent.
2. Establishment of a series of three total containment tailings ponds, effluent being decanted from one to the other, thus increasing the amount of settling time within the system.

3. Increasing the height of the existing dykes and extending the length of the east-west arm to create a complete retention system. An improved decant system should also be incorporated to insure that all effluent must pass through the system regardless of fluctuations in flow.

A combination of the above three alternatives is also a possibility.

## SUMMARY

During the summer of 1971, an investigation was made into the effects of a lead-zinc mine on the aquatic biology of Great Slave Lake. Twenty-five sampling locations were established at various points in and around the Cominco property at Pine Point, N.W.T.

Two litre surface water samples were collected bi-monthly from each station. Chemical analysis results were highly variable, although the levels of heavy metals found increased in the proximity of the mine. It was not possible to accurately determine chemistry changes between the mine and the lake.

Sediment and vegetation samples were collected monthly from several stations. Analysis results indicated a substantial area of the muskeg was being contaminated by mine effluent. Extremes in the heavy metal levels detected were attributed to inefficient operation of the tailings disposal system during periods of increased mill discharge or runoff. Greater amounts of the metals were concentrated in roots than in other sections of the plants.

Invertebrate samples were obtained monthly using an Ekman Dredge or Surber Sampler. No invertebrates of any species were found in the vicinity of the tailings area.

Gill nets of various mesh sizes were used to collect fish samples three times during the summer. Skinned fillets and livers were subjected to heavy metal analysis. Samples taken from the proximity of the mine generally contained greater amounts of zinc and copper than those from other areas. No relationship was found between heavy metal levels and fish weight, or between the levels and sampling time. No significant trends were noted in the levels of lead, cadmium, mercury,

nickel, iron, manganese or chlorinated hydrocarbons found. Token bioassay tests were conducted at four locations near the tailings disposal area. Heaviest mortality occurred within the first 48 hours. Suffocation was indicated as a principal cause of death.

Based on the few samples collected, it is concluded that a large area of the muskeg and, to a degree, the fish resources in the Pine Point area, are being contaminated by mine effluent. Existing tailings disposal facilities are inadequate to ensure that increased amounts of effluent do not reach Great Slave Lake. Recommendations for an improved system include the following alternatives:

- 1) Complete in-mill recycling of all effluent.
- 2) Establishment of a series of tailing ponds to increase settling time within the system.
- 3) Increase the heights and lengths of the existing dykes to create a complete retention system.

## ACKNOWLEDGEMENTS

The authors wish to thank Mr. C. T. Hatfield, Fisheries Service, Winnipeg, who made significant contributions to the study plans. Dr. H. V. Warren, Department of Geology, University of British Columbia, and Mr. D. Jamieson, Fisheries Service, Winnipeg, conducted the heavy metal analyses on fish, vegetation and mud samples. Dr. R. Duffy, Chemistry Department, University of Prince Edward Island, Charlottown, analysed samples for chlorinated hydrocarbon content. Water chemistry was done by the Water Quality Division, Environment Canada, Calgary.

Special thanks are also extended to Mr. R. H. Johnston, mill superintendant, Pine Point Mines, for his assistance in conducting the field portion of the study, and to Mr. B. Sutherland who identified invertebrate samples.

Mr. H. Trudeau and Mr. J. Hunt, Conservation and Protection Officers, Fisheries Service, were invaluable in conducting the field portion of this study.

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Appendix 1. Heavy metal content (ppm dry weight)  
 found in mud samples collected from  
 the area of Pine Point, N.W.T., and  
 analysed by Cominco Ltd., Trail, B.C.,  
 1971.

Station No.	Date	Pb	Cu	Zn
3	8/7/71	15.0	14.0	75.0
7	8/7/71	15.0	14.0	100.0
8	7/7/71	75.0	10.0	280.0
10	9/6/61	20.0	7.0	80.0
	8/7/71	8.0	11.0	55.0
11	5/6/71	7500.0	240.0	9500.0
13	2/6/71	10.0	12.0	70.0
	7/7/71	45.0	12.0	130.0
14	7/6/71	5500.0	220.0	8400.0
16	2/6/71	23.0	10.0	60.0
19	2/6/71	140.0	24.0	430.0
20	7/6/71	5500.0	150.0	5900.0
	5/7/71	4500.0	215.0	6700.0

Appendix 2. Heavy metal content (ppm dry weight) found in vegetation samples collected from the area of Pine Point, N.W.T., and analysed by Cominco Ltd., Trail, B.C., 1971.

Station	Date	Plant Spp.	Plant Section	Pb	Cu	Zn
3	8/7/71	Graminae Spp.	Mixed	6.0	18.0	70.0
7	8/7/71	Graminae Spp.	Mixed	2.0	6.0	25.0
10	8/7/71	Graminae Spp.	Mixed	2.0	4.5	20.0
16	9/7/71	Graminae Spp.	Mixed	1.0	1.0	70.0

Appendix 3. Results (ppm wet weight) of heavy metal analyses conducted  
on fish samples by Cominco Ltd., Trail, B.C., 1971.

Location	Species	Tissue	Zn	Cu	Pb	Cd
Presquille Pt.	White Fish	Muscle	3.2	0.1	<0.2	<0.2
		Liver	29.0	17.0	<0.5	<0.5
Presquille Pt.	White Fish	Muscle	3.6	0.2	<0.2	<0.2
		Liver	42.0	18.0	<0.5	<0.5
Presquille Pt.	Northern Pike	Muscle		No Sample Received		
		Liver	39.0	7.0	<0.5	<0.5
Presquille Pt.	Northern Pike	Muscle	4.4	0.2	<0.2	<0.2
		Liver		No Sample Received		
Presquille Pt.	Walleye	Muscle	4.2	0.2	<0.2	<0.2
		Liver		No Sample Received		
Buffalo River	Walleye	Muscle		No Sample Received		
		Liver	22.0	4.5	<0.5	<0.5
Buffalo River	N.R. Sucker	Muscle		No Sample Received		
		Liver	21.0	12.0	<0.5	<0.5
Buffalo River	N.R. Sucker	Muscle	4.8	0.7	<0.2	<0.2
		Liver		No Sample Received		
Little Buffalo R.	Northern Pike	Muscle		No Sample Received		
		Liver	46.0	8.0	<0.5	<0.5
Little Buffalo R.	White Fish	Muscle	3.1	0.2	<0.2	<0.2
		Liver		No Sample Received		
Little Buffalo R.	Northern Pike	Muscle		No Sample Received		
		Liver	27.0	10.0	<0.5	<0.5
Little Buffalo R.	Northern Pike	Muscle	3.6	0.2	<0.2	<0.2

Appendix 4. Comments.

After reviewing a draft of this paper, Cominco Ltd. offered comments, some of which are discussed below.

Cominco agreed that the existing tailings disposal system is not fully adequate, and claim engineering studies are presently underway to rectify the problem.

It has been concluded in this report that concentrations of dissolved lead were generally slightly higher in water samples taken from some lake and muskeg areas. Cominco pointed out that when results are in the parts per billion range, care should be taken when interpreting slight differences.

This report also states that zero lead values were found in some vegetation samples, and a few fish muscle and liver samples collected from the control area. Cominco felt that at least trace amounts of lead should have been detected.