Department of Environment
Environmental Protection Service
Pacific Region

AN ENVIRONMENTAL ASSESSMENT OF THE EFFECTS OF CASSIAR ASBESTOS CORPORATION ON CLINTON CREEK, YUKON TERRITORY

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by

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ABSTRACT

During the period 1974-1975, Environment Canada undertook an investigative program to assess the effects upon the receiving environment of Cassiar Asbestos Corporation Limited, Clinton Creek Mine, located in the Yukon Territory.

The environmental assessment program included chemical and biological sampling surveys initiated in the summer of 1974 and repeated in 1975.

The results presented in this report indicate significant adverse effects on the invertebrate communities and fish populations as a result of substrate alteration and the presence of asbestos fibres in the vicinity of the mine.

RESUME

Au cours de la période de 1974-1975, Environnement Canada a entrepis un programme de recherche visant à évaluer les effets de la Cassiar Asbestos Corporation Limited, Clinton Creek Mine, au Yukon, sur le milieu récepteur.

Le programme d'évaluation comprenait des études d'échantillonnages chimiques et biologiques qui ont été menées à l'été de 1974 et reprises en 1975.

Les résultats fournis dans le rapport indiquent la présence d'importants effets néfastes sur les communautés d'invertébrés et les populations de poissons, suite à une altération du substrat et à l'existence de fibres d'amiante à proximité de la mine.

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CONCLUSIONS

The water chemistry of the area near the tailings and waste rock pile (Stations 2, 4, 5, and 6) has been affected as indicated by elevated levels of calcium, magnesium, iron manganese, potassium, turbidity, and hardness. The values obtained are not significantly high to be considered harmful to aquatic organisms; however, these parameters should be continually monitored.

The samples analysed for asbestos fibre concentration in 1974 were within the expected range. However, the sample collected from Hudgeon Lake in 1975 had a higher asbestos fibre content in comparison to other background levels reported elsewhere in Canada. The fibre length determinations done in 1974 probably reflect the proximity to an airborne asbestos source. It is recommended that the asbestos fibre content of Hudgeon Lake, Clinton Creek, and the Fortymile River receive continual monitoring including fibre length determinations. The information obtained and presented in this report is limited but clarifies the need to do additional and more complete studies.

Invertebrate communities have been adversely affected by substrate alteration, particularly in the vicinity of the tailings pile (Station 4). The effects of the serpentine content of the substrate are evident as far as Station 7 on Clinton Creek.

The fish populations have also been adversely affected by the activities of the Clinton Creek mine. The absence of fish at Stations 1, 3, and 4 has been attributed to the impoundments responsible for the creation of Wolverine Lake and Hudgeon Lake. In addition, substrate alterations and subsequent lack of food organisms were contributing factors in explaining their absence.

The results of the histological studies indicate an additional detrimental effect on the fish populations directly attributable to the presence of asbestos fibres. The greatest number of fish showing separation of the lamellae epithelium of the gill tissue occurred in the greatest exposure group (16 day). It is recommended that these studies be continued.

1 INTRODUCTION

There are only two asbestos mines north of the 60th parallel in Canada; one is the Asbestos Hill Mine in Putunig, Quebec, and the other is the Clinton Creek Mine in the Yukon Territory. The Clinton Creek Mine is located 97 kilometers northwest of Dawson City and is owned and operated by Cassiar Asbestos Corporation Limited. The mine began production in October, 1967, and is expected to cease operation in the summer of 1978.

In response to discussions with the Department of Indian and Northern Development (DIAND) and concerns expressed by citizens of Clinton Creek, Environmental Protection Service (Yukon District) conducted an aquatic environmental quality survey. A chemical and biological sampling program was initiated in the summer of 1974 and was repeated in 1975 to expand the data base. This report presents the results of these surveys. It should provide a baseline to which future environmental effects and possibly post-operational stabilization activities may be related.

2 CASSIAR ASBESTOS CORPORATION LIMITED - CLINTON CREEK MINE

The Cassiar Asbestos Corporation Limited, Clinton Creek Mine, is an open pit asbestos mine located 64° 24.5' north latitude and 140° 36' west longitude. In 1975, it was the second highest mineral producer in the Yukon Territory.

The Clinton Creek deposit is an ultramafic body that occurs in metamorphic rocks, consisting mainly of black phyllite, platy black limestone, grey argillite and brown weathering micaceous gritty quartzite (Sinclair, 1975). The asbestos occurs almost entirely as cross-fibre veins, one-quarter inch wide or less (Sinclair et al, 1976).

The production rate in 1968 was approximately 2500 tons per day (tpd) and in 1974 and 1975, it increased to 4596 tpd and 5118 tpd, respectively (Table 1). In 1975, 1 407 453 tons of ore were milled with a recovery of 5.85 percent. At the close of 1975 the probable reserves were calculated at 4 773 000 tons. It is expected that the mine will cease operation in 1978 when the ore reserves will have been depleted.

By the end of 1975, after seven years of operation, an estimated 75 000 000 tons of waste had been removed from the mine.

TABLE 1 CLINTON CREEK MINE OPERATING SUMMARY - 1969-1975*

Year	Tons Milled	Rate (tons/day)	Grade (% recovery)	Reserves (Probable)	Reserves (Possible)
1969	952 889	3048	9.22		
1970	1 335 087	4049	7.82		
1971	1 447 863	4460	5.37	18 750 000	
1972	1 267 178	4400	5.66	9 250 000	9 500 000
1973	1 247 154	4838	5.64	7 861 123	8 792 000
1974	1 388 248	4596	4.37	6 524 725	461 000
1975	1 407 453	5118	5.85	4 773 000	928 931

* Craig and Laporte, 1972; Sinclair and Gilbert, 1975; Sinclair _et al_, 1976.

3 DESCRIPTION OF STUDY AREA

Clinton Creek is a left bank tributary to the Fortymile River, 4.8 kilometers southwest of its confluence with the Yukon River. The town of Clinton Creek is located 86 kilometers northwest of Dawson City, Yukon Territories, and is connected to the Yukon territorial highway system by a 30 kilometer access road. The open pit, mill, and mine are approximately 11 kilometers northwest of the townsite (Figure 1).

The mine is located in hilly, unglaciated terrain. There are three open pits: Porcupine, the largest; Snowshoe; and Creek. The Porcupine and Snowshoe pits are located on hills on the south side of Clinton Creek. Creek pit is on the original alignment of Porcupine Creek.

The waste rock overburden from the pits, consisting mainly of argillite, has been dumped in two main areas, Clinton dump and Porcupine dump. Clinton dump is located south of Clinton Creek and contains several tens of millions of tons of waste rock. Porcupine dump is much smaller and contains less than five million tons of waste (Golder & Associates, 1976). Both dumps extend across the original channels of Clinton and Porcupine creeks, respectively, as a result of waste material gradually creeping downslope. In the spring of 1974, the Clinton Creek channel was blocked, resulting in the formation of a lake (Hudgeon Lake) upstream of the toe of the dump (Figure 2).

The tailings pile from the mill is located on the west side of Wolverine Creek. In the spring of 1974, a large section of the tailings pile moved downslope and blocked the creek, forming Wolverine Lake upslope of the toe of the slide (Figure 3). The impoundment was breached in the summer of 1974 and reformed in the spring of 1975.

The study area centered on Clinton Creek as the drainage from the open pit, waste rock piles, and tailings all enter this stream.

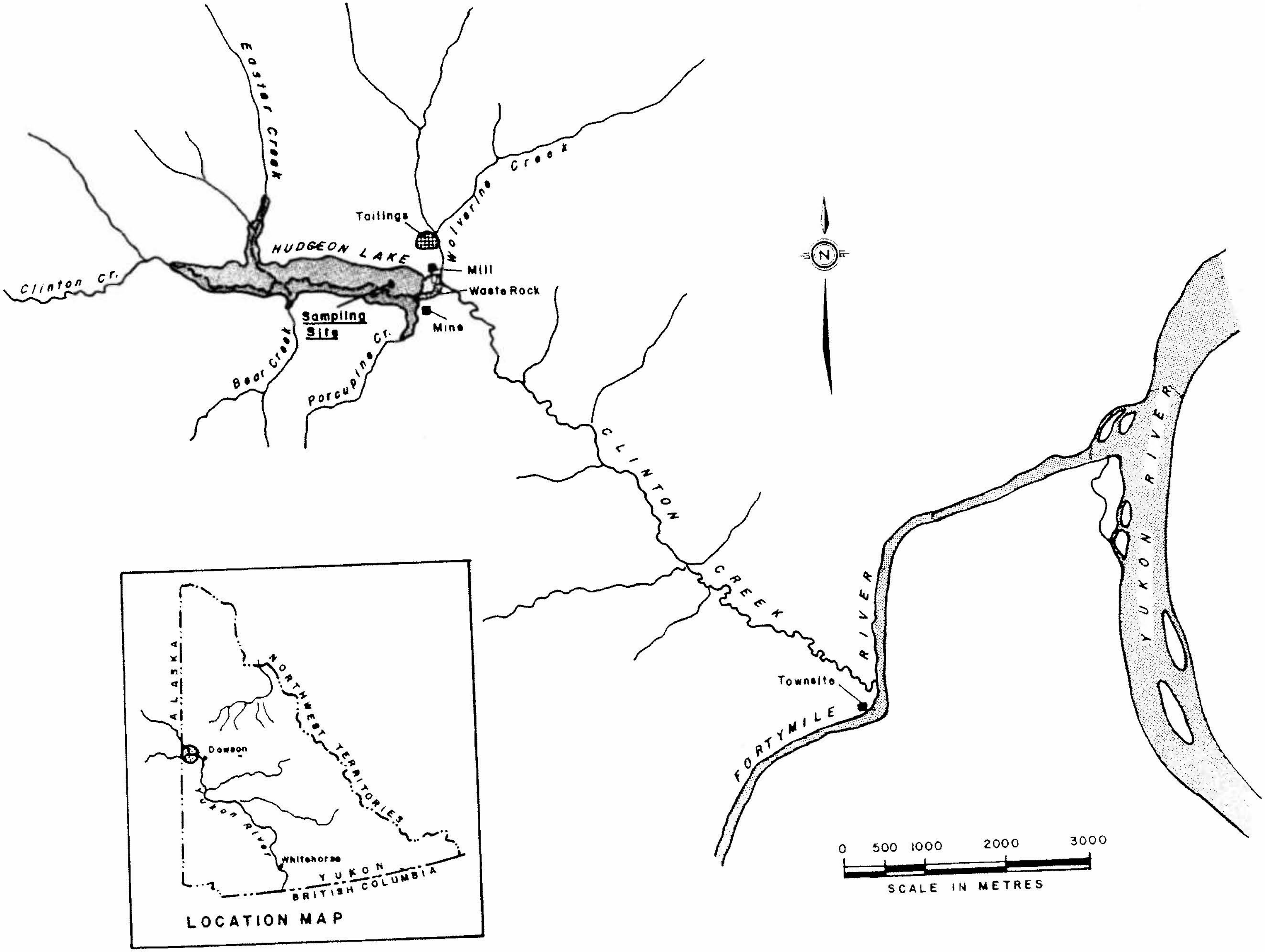

FIGURE I LOCATION MAP OF CASSIAR ASBESTOS CORPORATION LTD.

FIGURE 2 Hudgeon Lake (Formed by shifting of the waste rock - see Arrow A).

Arrow B shows approximate sampling location - histological assessment

FIGURE 3 Wolverine Creek (Trees laden with asbestos fibre).

4 METHODS AND MATERIALS

4.1 Sampling Stations

Nine stations were established for water quality and biological sampling. The stations are illustrated in Figure 4 and described in Table 2. All stations were marked by flagging nearby trees.

At the time of sampling, with the exception of Stations 1 and 8, these stations were located in shallow water with an average depth of 0.45 - 0.6 meters. The water depth at Stations 1 and 8 was approximately 1 meter.

Sampling sites which differ from those described above are outlined in the appropriate sections.

4.2 Water Quality Sampling

The water quality of Clinton Creek was assessed by collecting samples for chemical analyses, metal and non-metal parameters, asbestos fibre content, and toxicity (96 hr LC_{50}).

4.2.1 Water Chemistry. Samples were collected during the period August 6 to 9, 1974, and on June 26 and August 8, 1975, for chemical analysis. All water samples were analysed in the field for temperature, conductivity, dissolved oxygen, and pH. Temperature and conductivity were measured with a Yellow Springs Instrument Company Salinity-Conductivity-Temperature Meter. Dissolved oxygen content was measured by the azide modification of the Winkler Method (APHA, 1971); pH was determined using a Radiometer, Model 29B.

Additional samples were collected at all three sampling periods and analysed for the following: pH, non-filterable residue (NFR), total alkalinity, colour, total hardness, turbidity, and the metals; calcium (Ca), magnesium (Mg), cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), molybdenum (Mo), manganese (Mn), potassium (K), and zinc (Zn).

The samples which were collected in June, 1975, were lost in transit and not recovered. In 1975, the turbidity measurements were changed

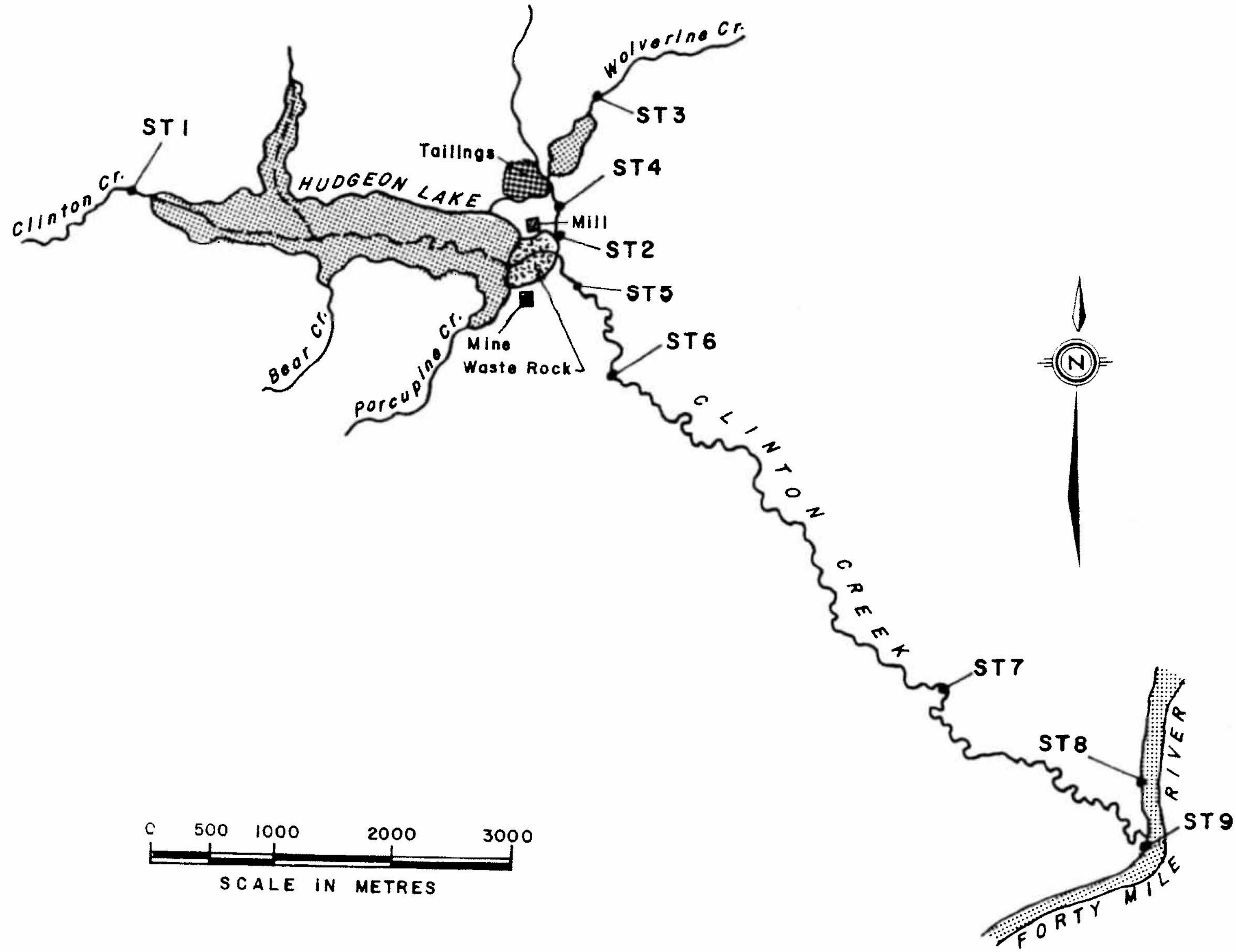

FIGURE 4 SAMPLE STATION LOCATIONS

TABLE 2 CLINTON CREEK MINE - 1974 AND 1975 SAMPLING STATIONS

Station	Location
1	On Clinton Creek above Hudgeon Lake;
2	On Clinton Creek below waste rock pile but above the confluence with Wolverine Creek;
3	On Wolverine Creek above Wolverine Lake;
4	On Wolverine Creek just above the confluence with Clinton Creek;
5	On Clinton Creek approximately 300 meters below the confluence of Wolverine Creek and Clinton Creek;
6	On Clinton Creek approximately 5 kilometers below Station 5;
7	On Clinton Creek, 100 meters above road leading to the townsite;
8	On the Fortymile River, 300 meters below the confluence of Clinton Creek and the Fortymile River;
9	On the Fortymile River, 100 meters above the confluence of Clinton Creek and the Fortymile River.

from Jackson Turbidity Units (JTU) used in 1974, to Formazin Turbidity Units (FTU). In 1975, the samples were also analysed for nickel (Ni), silver (Ag), and mercury (Hg). Manganese and potassium were not determined in 1975.

All samples were preserved and analysed at the Environmental Protection Service Chemistry Laboratory in West Vancouver, according to the methods described by Environment Canada (1974).

4.2.2 Asbestos Fibre Analysis. In November, 1974, DIAND collected 6 water samples for asbestos fibre analysis. Three samples were collected from Hudgeon Lake by the pumphouse for the mine water supply and 3 were collected from the Fortymile River by the pumphouse for the Clinton Creek townsite drinking water supply.

A qualitative and quantitative analysis was done on two samples from each area by Dr. R.W. Durham at the Canada Centre for Inland Waters in Burlington, Ontario.

4.2.3 Toxicity. Water samples were collected at Stations 2 and 4 on August 12, 1974, for static toxicity evaluation. The samples were collected in 5-gallon plastic jerry cans that were previously steam and acid cleaned, rinsed with sample water, then filled to capacity.

Static bioassays were conducted using Coho salmon (oncorhychus kisutch) fry at the Environmental Protection Service Bioassay Laboratory in West Vancouver according to Environment Canada (1974).

4.3 Biological Sampling

A biological assessment of Clinton Creek was conducted by obtaining qualitative and quantitative samples of aquatic invertebrates and fish. In addition, a histological analysis was conducted on gill tissue of Juvenile Coho salmon (oncorhynchus kisutch) which had been subjected to bioassays using water collected from Hudgeon Lake.

4.3.1 Invertebrates. Samples of aquatic invertebrates were obtained at all stations in August, 1974, and again in August, 1975.

In 1974, a circular sampler with an area of 1 sq ft (366 sq cm) was used to sample the stream beds. The sampler was turned into the stream bed, the enclosed substrate agitated, and the invertebrates removed from the screen. Three samples from each station were collected.

In 1975, artificial substrate samplers (ASS) were used to sample the invertebrate populations. The ASS were chrome-plated barbecue chicken baskets with an exterior diameter of 17 cm, and length of 25 cm. They were filled with rocks of a uniform size from the creek flood plain or creek bottom that had been wiped clean of debris and vegetation. The surface area contained in each basket was 6000 ± 1000 sq cm. Three samplers were submerged in the creek at each station and secured to the bank by a rope. The samplers were placed on station on June 26, 1975, and retrieved on August 8, 1975.

All samples were preserved in 70% methanol. The organisms were sorted and grouped into families at the Environmental Protection Service Laboratory in Whitehorse. In 1974, the final identification and enumeration was done by W. Robson, Technician, Environmental Protection Service, and in 1975 it was done by Dr. C. Low of Envirocon Limited.

The data obtained were analysed statistically on a Hewlett-Packard Model 9830A computer for diversity ($\bar{d}$) as described by Wilhm and Dorris, (1968), and for evenness of distribution (J) as described by Pielou, (1966). The formulas used in the calculations of these pollution indices are as follows:

$$\bar{d} = \sum_{i=1}^{s} \frac{n_i}{n} \log_2 \frac{n_i}{n}$$

$$J = \frac{-\sum \frac{n_i}{n} \log_2 \frac{n_i}{n}}{\log_a}$$

n_i = total number of individuals per taxon

n = total number of individuals per sample

s = total number of taxa

a = total number of species sampled

4.3.2 Fish. Fish populations were sampled from August 6 to 9, 1974, and August 6 to 7, 1975. A Smith-Root Type VIII Electro-Fisher and barrier nets were used at all stations. The barrier nets were placed downstream of the Electro-Fisher and approximately 30 meters of creek were fished before the nets were checked.

4.3.3 Histological Assessment. In March, 1975, two water samples were collected from Hudgeon Lake by the pumphouse for the mine water supply. These samples were collected by DIAND in two 45-gallon drums and forwarded to the Environmental Protection Service Laboratory in West Vancouver. Subsamples were forwarded to Dr. R.W. Durham, Canada Centre for Inland Waters, Burlington, Ontario, for asbestos fibre analysis (Durham and Pang, 1975).

The remaining sample was submitted to the Environmental Protection Service Bioassay Laboratory for bioassay determinations according to Environment Canada, (1974).

Juvenile Coho salmon (oncorhynchus kisutch) were used in all bioassays. Five fish were placed in each aquarium and the aquaria were aerated. Food was supplied to all fish and a mixing apparatus was used to keep the water circulating and the asbestos fibres in suspension. The following bioassays were conducted:

(a) 4 days at 100% concentration;
(b) 8 days at 100% concentration;
(c) 16 days at 100% concentration;
(d) 16 days at 100% concentration, then 16 days recovery in clean water.

After the termination of each bioassay, both the test and control fish were sacrificed. Gills were immediately dissected out and fixed in a 10% neutrally buffered formalin solution for histological examination.

The preparation of the gills for histological examination was done by Mr. J. Hollingdale, a research assistant at Simon Fraser University; this work was completed in April, 1975.

The gills were washed in tap water for 12 hours and then dehydrated by rinsing through a series of graded ethanol concentrations, cleaned in xylene, and embedded in tissue matt at 60°C. Sixty-one serial sections, 6 microns in thickness, were cut on a rotary microtome, placed on slides and stained with haematoxylin and eosin dyes.

Histological examination and assessment was done in December, 1976, by J. McBride, Research and Resource Services Directorate, Fisheries and Marine Service, West Vancouver, B.C. Each slide was evaluated for the percentage of tissue showing the following histological disorders:

(a) Separation of the Lamellae;

(b) Aneurysm;

(c) Hyperplasia.

5 RESULTS AND DISCUSSION

5.1 Water Chemistry

The water chemistry data are presented in Tables 3, 4, and Figures 5, 6, and 7. (Stations 2, 4, 5, and 6 appear to be affected by both the tailings pile on Wolverine Creek and the waste rock pile on Clinton Creek.) Elevated values for Calcium, Magnesium, Iron, Manganese, and Potassium are evident at Stations 2, 4, 5, and 6. The high magnesium levels are indicative of the brucite (MgO, H_2O) and magnesium carbonate in the orebody.

Corresponding higher values were obtained for hardness and turbidity at the same stations. The values obtained at Station 4 on Wolverine Creek are comparable to those at Stations 2, 5, and 6 on Clinton Creek, indicating that both the tailings pile and waste rock pile are having similar effects on the water quality. However, these values are not significantly high to be considered harmful to aquatic organisms.

Dissolved oxygen levels were within the expected range of 7 to 10 ppm with the exception of two lower values which were obtained in the 1974 measurements, 6.0 ppm at Station 2 and 4.3 ppm at Station 6.

All other chemical parameters measured did not appear to be affected by the mine.

5.2 Asbestos Fibre Analysis

Water samples from Hudgeon Lake and the Fortymile River were analysed for asbestos fibre concentration in November, 1974. The results obtained are presented in Table 5.

Asbestos fibre concentrations are reported in the number of chrysotile fibres per litre of water. Chrysotile is a fibrous form of serpentine and is the most common form found in the aquatic environment. The background level of asbestos in Canada and the northern United States surface waters varies between 1×10^5 fibres per litre and 1×10^7 fibres per litre (Lawrence and Zimmerman, 1977).

In March, 1975, in conjunction with the histological assessment study, an additional water sample from Hudgeon Lake was analysed for asbestos fibres.

TABLE 3 WATER CHEMISTRY RESULTS - NON-METAL

Stn	Sample Date	Temp 0°C	Conductivity umho/cm	DO (ppm)	pH Field	pH Lab	NFR (mg/l)	Total Alkalinity (CaCO3) (mg/l)	Colour CU	Total Hardness (CaCO3) (mg/l)	Turbidity*
1	7/8/74	5.5	145	9.5	7.4	7.7	<2.5	210.0	70	230	<0.5
	26/6/75	6.0	550	2.5	7.4						
	8/8/75	4.0	172	10.3	7.7		6.0	93.5	97	150	0.8
2	7/8/74	11.0	455	6.0	7.8	7.7	25.0	170.0	45	1200	75.0
	26/6/75	14.0	580	8.0	7.8						
	8/8/75	13.9	130	8.2	7.6		36.0	96.8	126	180	4.7
3	7/8/74	8.0	252	7.2	7.0	7.6	35.0	150.0	60	100	<0.5
	26/6/75	6.0	400	9.5	8.1						
	8/8/75	5.8	195	10.2	7.8		3.0	86.9	125	160	0.7
4	7/8/74	15.0	300	8.3	9.5	9.7	15.0	240.0	30	1100	46.0
	26/6/75	7.0	500	6.5	9.2						
	8/8/75	6.0	315	9.6	8.8		61.0	131.0	93	360	10.0
5	7/8/74	14.0	385	7.4	8.3	9.0	4.0	220.0	35	1400	48.0
	26/6/75	13.5	590	8.4	8.9						
	8/8/75	14.0	230	8.1	7.3		28.0	99.0	112	250	3.5
6	7/8/74	13.0	375	4.3	7.0	7.2	<2.5	320.0	25	1200	9.7
	26/6/75	13.5	700	7.5	7.2						
	8/8/75	13.5	380	8.0	7.8		29.0	125.0	115	290	13.0
7	7/8/74	9.5	280	9.3	7.5	7.9	2.5	210.0	60	380	1.2
	26/6/75	13.5	600	9.5	8.0						
	8/8/75	8.7	285	9.1	7.8		62.0	93.5	122	290	12.0
8	7/8/74	13.8	220		7.9	7.7	<2.5	110.0	55	140	0.7
	26/6/75	13.0	300	9.0	8.1						
	8/8/75	12.8	240	8.7	7.8		52.0	129.0	131	190	20.0
9	7/8/74	15.0	132		7.8	7.2	2.8	59.0	25	34	<0.5
	26/6/75	12.5	130	8.2	8.1						
	8/8/75	12.0	80	8.7	7.6		17.0	40.7	109	48	2.2

* 1974 Jackson Turbidity Units (JTU); 1975 Formazin Turbidity Units (FTU)

TABLE 4 WATER CHEMISTRY RESULTS - TOTAL METALS

Stn	Sample Date	Ca (ppm)	Mg (ppm)	Cd (ppm)	Cu (ppm)	Fe (ppm)	Pb (ppm)	Mo (ppm)	Ni (ppm)	Mn (ppm)	K (ppm)	Ag (ppm)	Zn (ppm)	Hg (ppb)
1	7/8/74	30.0	37.0	<0.1	<0.1	0.15	<0.1	<0.3		<0.03	0.40		<0.01	
	26/6/75													
	8/8/75	32.0	16.0	<0.1	<0.1	0.23	<0.2	<0.3	<0.05			<0.03	<0.01	<0.15
2	7/8/74	110.0	220.0	<0.1	<0.1	1.30	<0.2	<0.3		0.59	2.50		<0.01	
	26/6/75													
	8/8/75	37.0	21.5	<0.1	<0.1	1.30	<0.2	<0.3	<0.05			<0.03	<0.01	<0.15
3	7/8/74	39.0	2.7	<0.1	<0.1	0.28	<0.1	<0.3		<0.03	0.71		<0.01	
	26/6/75													
	8/8/75	28.0	22.5	<0.1	<0.1	0.25	<0.2	<0.3	<0.05			<0.03	<0.01	<0.15
4	7/8/74	5.0	270.0	<0.1	<0.1	2.10	<0.1	<0.3		0.14	1.90		<0.01	
	26/6/75													
	8/8/75	46.0	60.5	<0.1	<0.1	1.60	<0.2	<0.3	0.10			<0.03	<0.01	<0.15
5	7/8/74	63.0	210.0	<0.1	<0.1	1.90	<0.1	<0.3		0.39	2.20		<0.01	
	26/6/75													
	8/8/75	48.0	31.5	<0.1	<0.1	0.90	<0.2	<0.3	<0.05			<0.03	<0.01	<0.15
6	7/8/74	5.9	280.0	<0.1	<0.1	0.66	<0.1	<0.3		0.29	2.20		<0.01	
	26/6/75													
	8/8/75	48.0	42.0	<0.1	<0.1	1.40	<0.2	<0.3	0.07			<0.03	<0.01	<0.15
7	7/8/74	40.0	70.0	<0.1	<0.1	0.14	<0.1	<0.3		0.17	1.30		<0.01	
	26/6/75													
	8/8/75	46.0	42.5	<0.1	<0.1	1.50	<0.2	<0.3	0.09			<0.03	<0.01	<0.15
8	7/5/74	16.0	24.0	<0.1	<0.1	0.12	<0.1	<0.3		0.12	1.30		<0.01	
	26/6/75													
	8/8/75	31.0	27.0	<0.1	<0.1	1.10	<0.2	<0.3	0.06			<0.03	<0.01	<0.15
9	7/8/74	12.0	0.7	<0.1	<0.1	0.07	<0.1	<0.3		0.08	0.97		<0.01	
	26/6/75													
	8/8/75	27.0	4.3	<0.1	<0.1	0.6	<0.2	<0.3	<0.05			<0.03	<0.01	<0.15

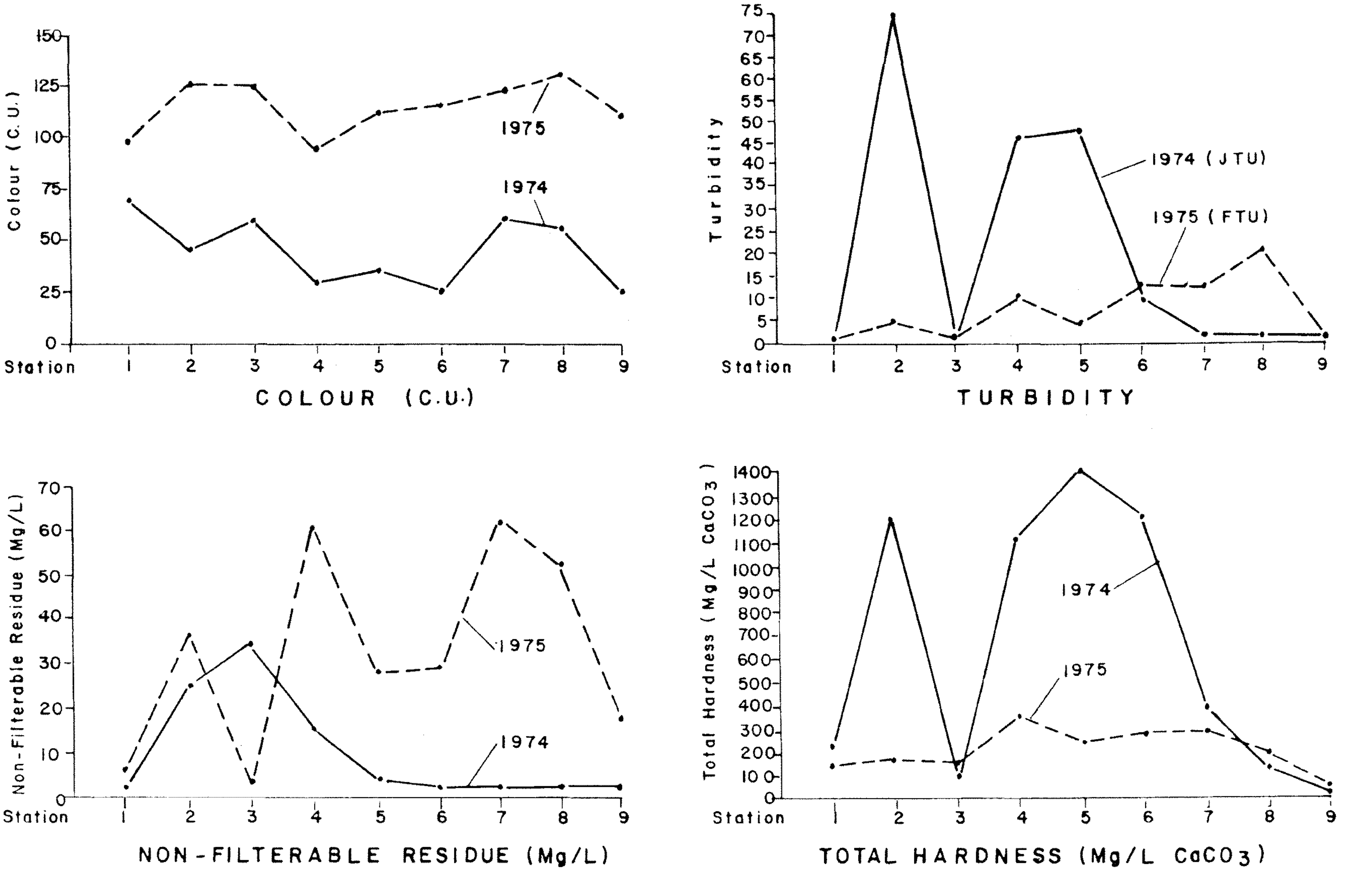

FIGURE 5 WATER CHEMISTRY RESULTS - NON-METALS COLOUR, TURBIDITY, NON-FILTERABLE RESIDUE, TOTAL HARDNESS

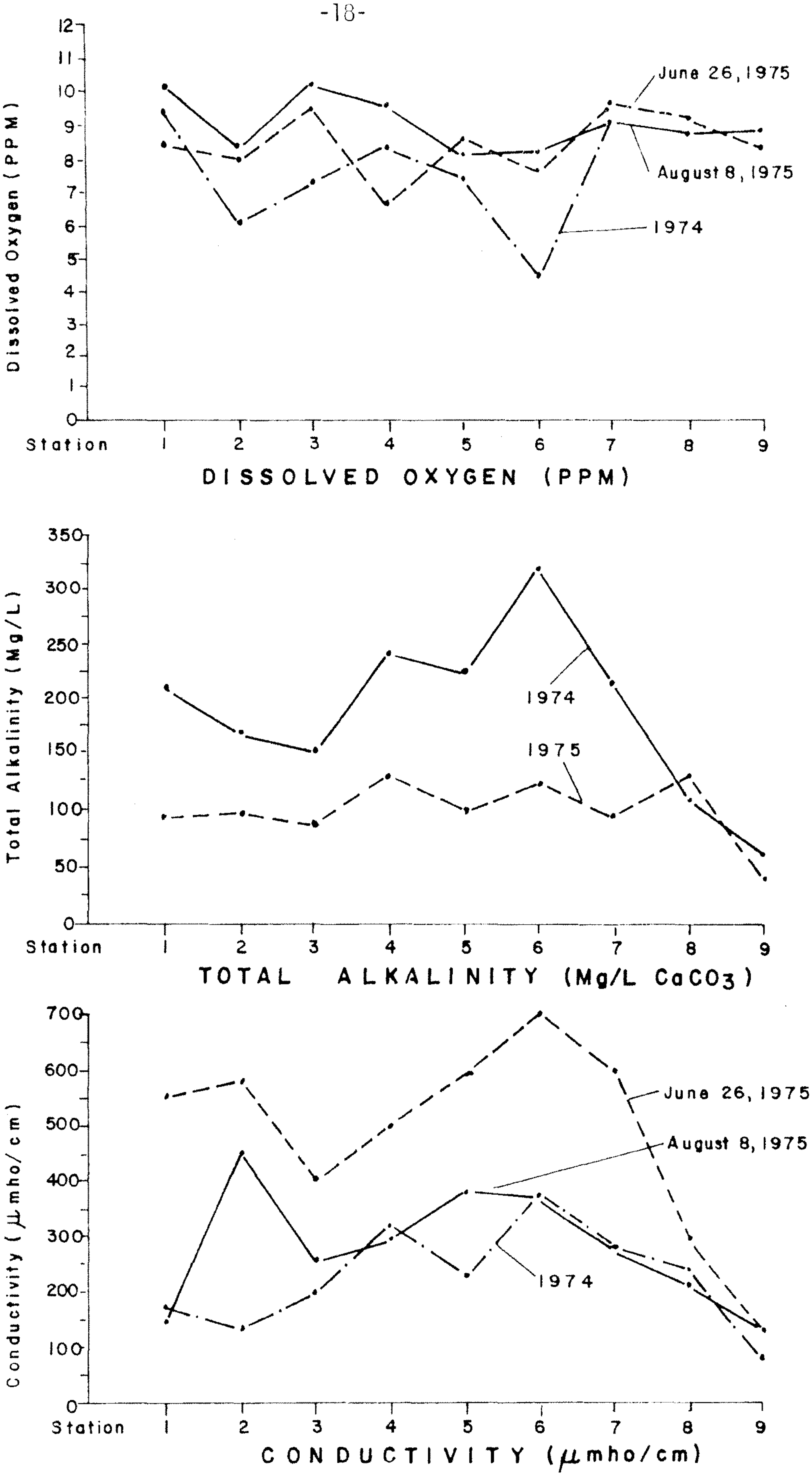

FIGURE 6 WATER CHEMISTRY RESULTS - NON-METALS
DISSOLVED OXYGEN, TOTAL ALKALINITY, CONDUCTIVITY

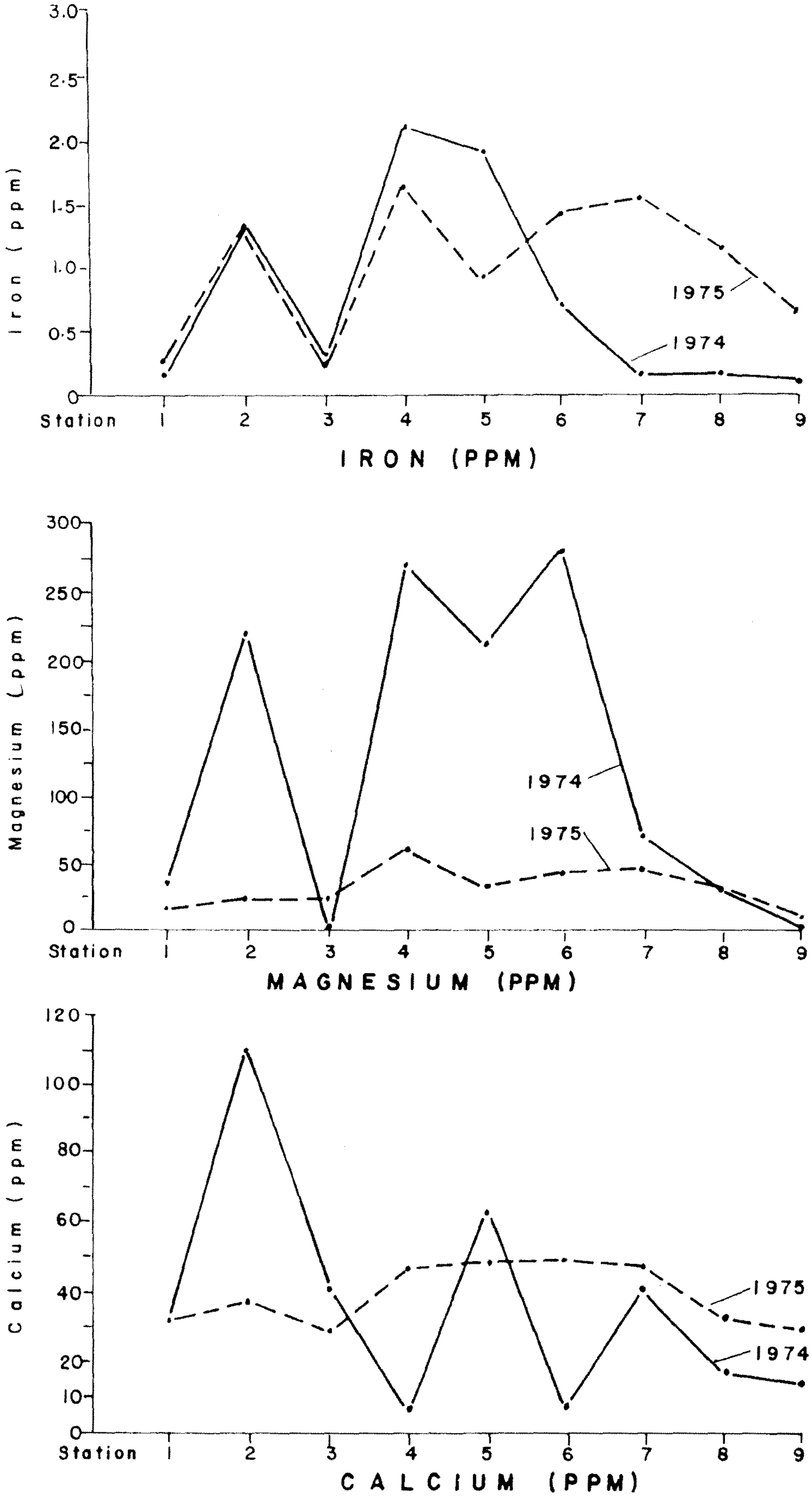

FIGURE 7 WATER CHEMISTRY RESULTS - METALS
IRON, MAGNESIUM, CALCIUM

TABLE 5 ASBESTOS FIBRES IN WATER SAMPLES FROM HUDGEON LAKE AND FORTYMILE RIVER

Station	Date	Time	Concentration No. of Fibres per litre	Mean Fibre Size (μm)
Hudgeon Lake by pumphouse for mine water supply	22/10/74	12:45	36.4×10^6	1.0
Hudgeon Lake by pumphouse for mine water supply	23/10/74	10:30	46.6×10^6	1.0
Fortymile River by pumphouse for Clinton Creek water supply	22/10/74	14:40	10^5 (Detection Limit)	-
Fortymile River by pumphouse for Clinton Creek water supply	23/10/74	08:30	3.0×10^6	1.5
Hudgeon Lake by pumphouse for mine water supply	03/75	-	$300 \pm 80 \times 10^6$	-

The results obtained on the Fortymile River near the pumphouse for the Clinton Creek water supply are typical of most surface waters measured elsewhere in Canada.

The fibre concentration in the samples from Hudgeon Lake are appreciably higher than those from the Fortymile River. The results obtained in 1974 are within the range of values that have been reported for raw water supplies. The fibre content found in 1975 ($300 \pm 80 \times 10^6$ fibres per litre) at Hudgeon Lake is high in comparison to the 1974 samples and in comparison to other background levels reported (Kay, 1973).

The mean fibre length of the 1974 samples ranged from 1.0 μm to 1.5 μm. This is considerably higher than natural fibre length averages of 0.2 μm. This probably reflects the proximity to an airborne asbestos source (Durham, 1976). Fibre length determinations were not obtained for the 1975 sample.

5.3 Toxicity

The bioassay results for water samples collected from Stations 2 and 4 are presented in Table 6. The samples were found to be non-toxic at 100% concentration over 96 hours. These results confirm the water chemistry statistics.

Additional bioassays were conducted as part of the histological assessment study done in 1975. These bioassays were done on the Hudgeon Lake water sample and were also non-toxic at 100% concentration for over 96 hours. Subsequent bioassays were carried out for 8 and 16 days and were also non-toxic.

5.4 Invertebrates

The use of the modified circular sampler for aquatic invertebrate collection in 1974 was not adaptable to the substrates encountered. Few organisms were collected and consequently the results were disregarded. The results of the sampling program in 1975 using artificial substrate samplers are considered representative of the invertebrate communities in the study area. The population summary and species list are presented in Tables 7 and 8.

TABLE 6 TOXICITY EVALUATION - 96 HR LC_{50} BIOASSAY RESULTS

Station	Station Location	Date Sampled	Date Bioassay	Initial Sample pH	Final Sample pH	Temp Range 0°C	Loading Density (g/l)	Percent Survival 96 Hour	96 Hr LC_{50}
2	Clinton Creek	12/8/74	16/8/74	8.93	8.21	12±1	1.22	100	Not Established
4	Wolverine Creek	12/8/74	16/8/74	9.74	8.69	12±1	1.22	100	Not Established

Test Fish - Juvenile Coho Salmon (Oncorhychus kisutch) acclimated to untreated Capilano Reservoir Tap Water at 11°C + 1°C.
- Mean Fish Weight 4.91 g
- Mean Fish Length 7.5 cm
- Test Tank Volume 20 kilo

TABLE 7 MACRO INVERTEBRATE POPULATION, CLINTON CREEK MINE - AUGUST, 1975

	Stations																										
	1			2			3			4			5			6			7			8			9		
Species	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Hydracarina sp	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Synurella sp	1	14	-	-	-	-	9	6	10	-	-	-	-	-	-	-	-	-	3	5	2	-	-	-	-	-	-
Moina macropa	-	-	-	3	3	-	-	-	-	-	-	-	3	107	2	18	-	-	-	-	-	-	-	-	-	-	-
Chaoborus sp	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Systenus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Roederiodes sp	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	4	2	-	-	-	-	-	-
Muscidae sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Corynoneura sp	1	-	1	8	-	-	2	-	-	-	-	-	1	-	2	-	-	-	60	34	72	-	30	175	-	-	-
Crictopus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Spaniotoma sp	-	-	16	6	-	3	-	-	17	-	-	-	-	-	4	2	-	-	6	3	15	-	-	4	-	-	-
Pentaneura sp	-	-	-	-	-	1	10	4	-	-	-	-	-	-	-	-	-	-	17	9	-	-	1	3	-	-	1
Procladius sp	-	-	-	14	1	6	8	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tendipes																											
(=Chironomus) sp	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tendipedidae sp pupa	-	1	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	2	-	1	4	-	-	-
Chrysops sp	-	-	1	1	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-
Longurio sp	4	4	4	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Tipula sp a	-	1	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Tipula sp b	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tipula sp c	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Simulidae sp	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brachycera sp pupa	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baetis sp	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Centroptilum sp	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Cinygmula sp	2	6	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hemiptera sp nymph	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Perloymia sp	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemoura sp	2	4	1	-	-	-	6	5	14	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Isogenus sp	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctopsyche sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Platycentropus sp	-	-	-	-	-	-	-	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligochaeta sp	-	-	5	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 8 INVERTEBRATE SPECIES LIST - AUGUST, 1975

Phylum Arthropoda
Class Arachnida (Arachneidea)
Order Hydracarina
Hydracarina sp

Class Crustacea
Order Amphipoda
Family Gammaridae
Synurella (*bifurca* or *johanseni*)

Order Cladocera
Sub Order Calyptomera
Family Daphnidae
prob. *Moina macropa*

Class Insecta
Order Diptera
Family Culicidae
Sub family Chaoborinae
Chaoborus sp

Family Dolichopodidae
prob. *Systenus* sp

Family Empididae
Hemerodromia sp
Roederiodes sp

Family Muscidae
Muscidae sp

Family Tendipedidae
Sub family Hydrobaeninae
Corynoneura sp
Cricotopus sp
Spaniotoma sp
Sub family Pelopiinae
Pentaneura sp
Procladius sp
Sub family Tendipedinae (Chironominae)
Tendipes (*Chironomus*) sp
Adult Chironomidae
Tendipedidae sp pupa

Family Tabanidae
Chrysops sp

(continued)

TABLE 8 (continued)

Family Tipulidae
- *Longurio* sp
- *Tipula* sp a
- *Tipula* sp b
- *Tipula* sp c
- *Tipula* sp d

Family Simuliidae (Melusinidae)
- Simuliidae sp

- Brachycera pupa

Order Ephemeroptera

Family Baetidae
- *Baetis* sp
- *Centroptilum* sp

Family Heptageniidae
- *Cinygmula* sp

Order Hemiptera
- Hemiptera sp. nymph

Order Plecoptera

Family Nemouridae

Sub family Leucrinae
- *Perloymia* sp

Sub family Nemourinae
- *Nemoura* sp

Family Perlodidae

Sub family Isogeninae
- *Isogenus* sp

Order Tricoptera

Family Hydropsychidae
- *Arctopsyche* sp

Family Limnephilidae
- *Platycentropus* sp

Phylum Annelida

Class Oligochaeta
- Oligochaeta sp

A total of 32 species representing 2 phyla were found. Insects dominated the populations in terms of total numbers at all stations, with the exception of Station 5. The community structure at the control Stations 1 and 3 was similar. The cladoceran, Moina macropa, was the dominant organism at Station 5. The insect most prevalent was the midge corynoneura.

The absence of invertebrates at Station 4 is likely related to the substrate. The water from Wolverine Lake flows past the toe of the tailings site and is dispersed into the tailings which have been deposited in the creek bed. The water surfaces again approximately 100 meters downstream and flows through braided channels until the confluence with Clinton Creek. The tailings pile is composed of crushed serpentine (particle size ± 0.6 cm) and asbestos fibres. The asbestos fibres are readily transported by the flowing waters of Wolverine Creek, leaving the serpentine to form the primary substrate. This substrate also shifts with increased water flows, making it a poor habitat for aquatic invertebrates.

The diversity-evenness results are presented in Table 9. Stations 1, 2, 3, and 7 had the greatest diversity, Stations 1 and 3 being slightly higher than 2 and 7. The low diversity results obtained for Stations 5 and 6 can be attributed to the particulate serpentine which moves into Clinton Creek. The serpentine content of the substrate at Station 7 is far less than at stations upstream. The higher diversity index reflects the improved habitat.

Varying quantities of asbestos fibres were present in the samplers at all except Stations 1 and 3. Station 8 was plugged with fibres to a much greater extent than any other station. The Fortymile River is a slower moving, deeper waterway than Clinton Creek and it is likely that the asbestos fibres settle out because of these characteristics. In addition to having the greatest concentration of asbestos fibres in the sampler, Station 8 had the greatest number of individuals.

The absence of organisms at Station 9 is due to the large fluctuation in water level at that location.

TABLE 9 DIVERSITY AND EVENNESS RESULTS, INVERTEBRATE POPULATION, CLINTON CREEK MINE - AUGUST, 1975

Station	Sample	Total Number of Individuals	Number of Taxa	Diversity Index	Evenness
1	A	14	8	2.807	0.936
	B	33	7	2.330	0.830
	C	29	7	1.975	0.703
2	A	36	9	2.460	0.776
	B	6	3	1.459	0.921
	C	12	5	1.896	0.817
3	A	40	8	2.622	0.874
	B	29	7	2.643	0.941
	C	48	8	2.236	0.745
4	A	0	0	0	0
	B	0	0	0	0
	C	0	0	0	0
5	A	4	2	0.811	0.811
	B	108	2	0.076	0.076
	C	10	5	2.122	0.914
6	A	22	4	0.957	0.478
	B	0	0	0	0
	C	0	0	0	0
7	A	88	6	1.412	0.546
	B	60	10	2.142	0.645
	C	94	6	1.141	0.442
8	A	0	0	0	0
	B	33	4	0.584	0.292
	C	186	4	0.417	0.209
9	A	0	0	0	0
	B	0	0	0	0
	C	3	2	0.918	0.918

5.5 Fish

The electro-fishing results are presented in Table 10. Fish were found at all stations with the exception of Station 1, 3, and 4. The absence of fish at Station 1 is related to two factors: Clinton Creek upstream of Hudgeon Lake freezes during the winter; and, the area between Station 2 and Hudgeon Lake is impassable. It is suspected that prior to the formation of Hudgeon Lake, fish could have inhabited the upper reaches of Clinton Creek during the summer months. The absence of fish at Station 3 can be explained by similar circumstances. The absence of fish at Station 4 was due to the lack of water and the inability of the fish to pass through the culvert at the mouth of Wolverine Creek. The lack of food organisms and substrate characteristics were also contributing factors in explaining their absence.

The remaining stations were well populated by various species of fish. The most numerous and represented fish were the Longnose Sucker (*Catostomus catostomus*) and the Arctic Grayling (*Thymallus arcticus*).

5.6 Histological Assessment

Tables 11 and 12 summarize the gill tissue structural changes sustained by the various experimental and control fish. The disorders identified and their significance are as follows:

(a) Separation of the Lamellae Epithelium

This signifies the dislodgement of the gill lamellae epithelia from the base membrane. It is a common response to toxicants in general (Figure 8).

(b) Hyperplasis

This signifies an increase in the epithelia cells of the gill lamellae, also considered a common response to external irritants (Figure 9).

(c) Aneurysm

This is a weakness in the blood vessel wall. The histopathology is unknown but this weakness is not commonly present in healthy fish (Figure 10).

TABLE 10 ELECTRO-FISHING RESULTS - AUGUST 6-7, 1975

Scientific Name	Common Name	Total Number at Stations 1	2	3	4	5	6	7	8	9
Catostomus catostomus (Forster)	Longnose sucker	-	1	-	-	4	2	3	5	5
Coregonus clupeaformis (Mitchell)	Lake whitefish	-	-	-	-	-	-	1	-	-
Cottus cognatus (Richardson)	Slimy sculpin	-	1	-	-	-	1	3	1	2
Oncorhynchus tshawytscha (Walbaum)	Chinook salmon	-	-	-	-	-	-	-	-	2
Prosopium cylindraceum (Pallas)	Round whitefish	-	2	-	-	-	-	1	-	-
Thymallus arcticus (Pallas)	Arctic grayling	-	14	-	-	2	1	2	2	2

TABLE 11 HISTOLOGICAL ASSESSMENT - SLIDES ANALYSED

Treatment	Separation of Lamellae Epithelium % of Gill Tissue Affected				Hyperplasm Present	Aneurysm Present
	0%	10%	10-50%	50-100%		
4 Days' Control						
Slide 13	X	-	-	-	-	-
16	X	-	-	-	-	-
23	X	-	-	-	-	-
28	X	-	-	-	-	-
33	X	-	-	-	-	-
37	X	-	-	-	-	-
41	X	-	-	-	-	-
42	X	-	-	-	-	-
51	X	-	-	-	-	-
61	X	-	-	-	-	-
4 Days' Exposure						
Slide 4	X	-	-	-	-	-
10	X	-	-	-	-	-
17	X	-	-	-	-	-
29	-	X	-	-	-	-
38	-	X	-	-	-	-
43	-	-	X	-	-	-
47	-	X	-	-	-	-
50	X	-	-	-	-	-
8 Days' Control						
Slide 1	X	-	-	-	-	-
5	X	-	-	-	-	X
21	-	X	-	-	-	-
24	X	-	-	-	X	-
30	-	-	X	-	X	X
40	X	-	-	-	-	-
44	X	-	-	-	X	-
53	X	-	-	-	-	-
55	X	-	-	-	-	-
57	X	-	-	-	-	-
8 Days' Exposure						
Slide 3	-	X	-	-	X	-
6	-	X	-	-	-	-
11	-	-	X	-	-	-
15	-	-	X	-	-	-
20	-	X	-	-	-	-
25	-	X	-	-	-	-
31	-	X	-	-	-	-
34	-	X	-	-	-	-
36	-	X	-	-	-	-
39	-	X	-	-	-	-
45	-	X	-	-	-	-
48	-	X	-	-	-	-
52	X	-	-	-	-	-
16 Days' Exposure						
Slide 8	-	-	-	X	-	-
9	-	-	-	X	-	-
14	-	-	-	X	-	-
18	-	-	X	-	-	-
22	-	-	-	X	-	-
26	-	-	-	X	-	-
49	-	-	-	X	-	-
56	-	-	-	X	-	-
58	-	-	-	X	-	-
60	-	X	-	-	-	-
16 Days' Exposure and 16 Days' Recovery						
Slide 2	X	-	-	-	X	X
7	-	X	-	-	X	X
12	-	-	X	-	-	-
19	-	X	-	-	-	-
27	-	X	-	-	-	-
32	-	X	-	-	-	-
35	-	X	-	-	-	-
46	-	X	-	-	-	-
54	X	-	-	-	-	-
59	-	X	-	-	-	-

TABLE 12 HISTOLOGICAL ASSESSMENT OF GILL TISSUE (ONCORHYNCHUS KISUTCH)

Percentage of Slides Showing the Following Histological Disorders

Treatment	Separation of Lamellae Epithelium 0%	10%	10-50%	50-100%	Hyperplasm	Aneurysm
4 days' control	100.0	-	-	-	-	-
4 days' exposure	50.0	37.5	12.5	-	-	-
8 days' control	80.0	10.0	10.0	-	30.0	20.0
8 days' exposure	7.7	76.9	15.4	-	7.7	-
16 days' exposure	-	10.0	10.0	80.0	-	-
16 days' exposure with 16 days' recovery	20.0	70.0	10.0	-	20.0	20.0

FIGURE 8 Gill Tissue from Laboratory Juvenile Coho Salmon Exposed to 100% Concentration of Hudgeon Lake Water for 16 Days

Arrows point to areas which have separation of lamellae epithelium.

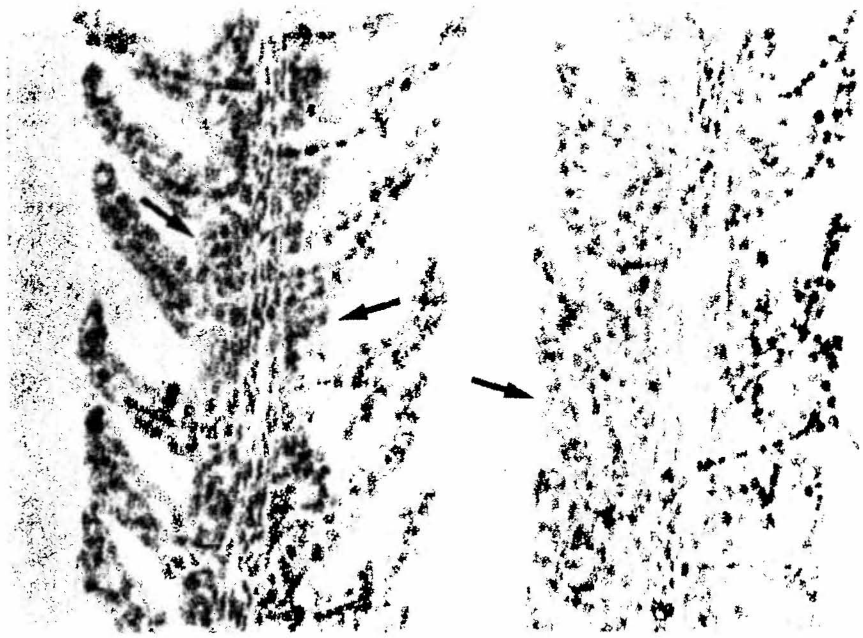

FIGURE 9 Gill Tissue from Laboratory Juvenile Coho Salmon Exposed to 100% Concentration of Hudgeon Lake Water for 16 Days

Arrows indicate hyperplasia of lamellae epithelium.

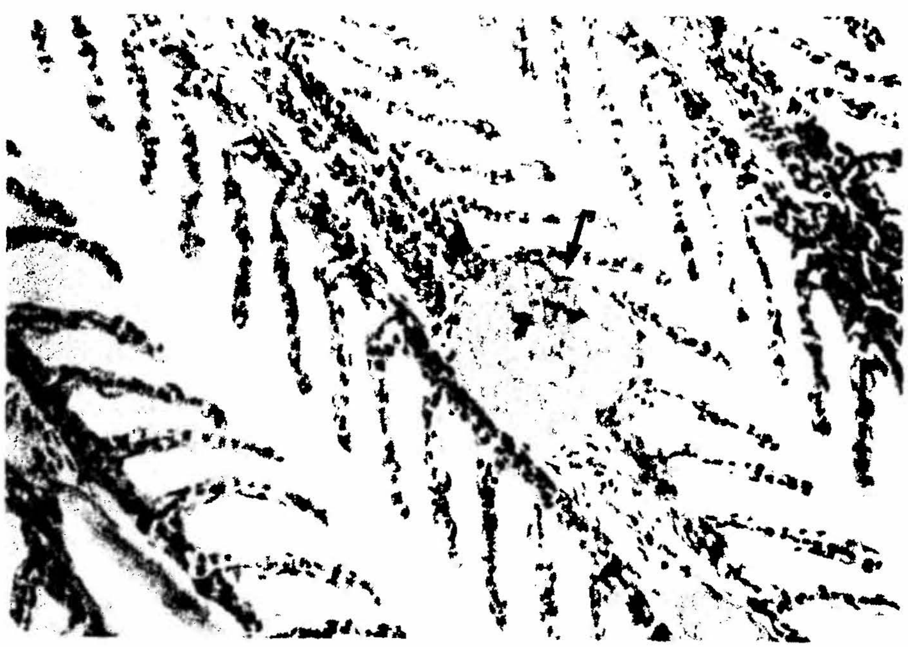

FIGURE 10 Gill Tissue from Laboratory Juvenile Coho Salmon Exposed to 100% Concentration of Hudgeon Lake Water for 16 Days

Arrow shows location of Aneurysm.

The 16-day exposure group showed the highest incidence of separation of the lamellae epithelium. Eighty percent of the slides analysed displayed 50 - 100% separation. Seventy percent of the slides of the 16-day exposure/16-day recovery group displayed 10% separation. These results indicate that this disorder became more prevalent with a greater exposure time and also that the fish recovered substantially after being exposed to clean water.

Both experimental and control fish displayed signs of hyperplasia and development of aneurysm and consequently these disorders cannot be attributed to the presence of asbestos fibres.

There has been limited research done on the effects of physical irritants to fish gill tisues. Smith (1966) found that the Fathead minnow (Pimephales promelas) show an inverse relationship between oxygen uptake and the concentration of wood fibres; i.e., the higher the concentration of fibres, the lower the oxygen uptake. Smith (1966) also found that fish which were previously exposed to wood fibres had metabolic levels similar to the control fish, indicating that previous exposure to wood fibres did not cause a permanently depressed metabolic level. Smith (1966) also measured oxygen uptake and his results indicated that suspended wood fibres greatly affect a fish's ability to extract oxygen from water. When exposed to lethal concentrations of wood fibres, the fish showed signs of anoxia. When he investigated the gill tissue, it was found that the test fish had responded by increasing the production of mucus and that a large amount of mucus was present between the gill lamellae. In some instances the lamellae showed signs of malformation and fusion. Since gills serve as a respiratory and osmoregulatory organ, fish are required to circulate a large volume of water over their gills. Gills are affected and damaged when they are exposed to chemical toxicants and physical irritants (Smith, 1966; Cope, 1966; Gilderhus, 1966; Migaki and Ribelin, 1975; Skidmore, 1970).

The present knowledge of the effects of asbestos fibres on aquatic organisms is very limited.

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