ASSESSMENT OF THE EFFECTS OF THE CLINTON CREEK MINE WASTE DUMP AND TAILINGS, YUKON TERRITORY

Prepared For

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Project 951

April, 1981

E.V.S. consultants ltd.

April 2, 1981 OUR FILE: 951

Mr. J.D. Little
Cassiar Resources Ltd.
#2000-1055 West Hastings Street
Vancouver, B.C.
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Dear Mr. Little

Re: Assessment of the Effects of the Clinton Creek Mine Waste Dump and Tailings, Yukon Territories

I am pleased to enclose our final report describing the findings and conclusions of our investigations.

It is our overall conclusion from the available data that the level of concern regarding environmental health hazards and fisheries impacts of asbestos is less than that expressed by Yukon Government agencies. The concerns expressed by agency representatives emphasize potential hazards rather than demonstrable effects, although some adverse impacts of the mining operations were identified in the Clinton Creek watershed. Specifically our conclusions can be summarized as follows:

1. Fisheries habitat was negatively affected in an approximately 0.5 kilometer section of Clinton Creek. The formation of Hudgeon Lake appears to have enhanced the grayling population and food supply for the watershed. However, net gain or loss of fisheries resources could not be defined by the present study.
2. Asbestos levels in the receiving waters of Clinton Creek declined from 1978 to 1980; however natural asbestos levels in the Forty Mile River were high and generally comparable to levels in Clinton Creek over the same time period.
3. Correlations of asbestos fiber concentrations in potable water with increases in gastrointestinal cancer were generally inconclusive; estimated risk factors indicated a low level of hazard over a 70 year lifetime of ingestion.

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We would be pleased to discuss these conclusions and any component of the report at your convenience.

Please feel free to contact us at any time.

Yours truly,

E.V.S. CONSULTANTS LTD.

G.A. Vigers, Ph.D.
President

GAV:dcm

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ACKNOWLEDGEMENTS

The authors wish to sincerely thank a number of people for their assistance and cooperation during the course of this study.

We acknowledge the accomodation and assistance provided by Cassiar Resources Ltd. and Dave Acason during the field study at Clinton Creek, and Pat Hartin for providing reference material from Cassiar Resources Ltd. Library.

A.J. Shaw of B.H. Levelton and Associates Ltd. provided data and information regarding water sampling for asbestos fibers.

E.V.S. Consultants Ltd. would like to acknowledge the principal investigators, P.W. Delaney, R.W. Stewart, D. Konasewich and G.A. Vigers who undertook this assignment; and the following members of E.V.S. Consultants Ltd. staff, J. Coustalin for field/lab work, D. MacNicol and D. Prissick for typing and L. Borleske for drafting.

1.0 INTRODUCTION

The Yukon Water Board has expressed a number of concerns regarding mining activities in the Clinton Creek watershed.

Specifically these concerns are:

1. The effects of erosion and destabilization of the slumping waste piles on the fishery resource and instream habitat of Clinton and Wolverine Creeks.

2. The contribution of asbestos fibers, from erosion of the waste piles on Clinton Creek, to the total asbestos load in the Forty Mile watershed.

3. The hazard and environmental risk associated with the ingestion of asbestos fibers in drinking water supplies derived from the Forty Mile River.

To address these concerns, Cassiar Resources Ltd. commissioned studies to undertake a field assessment of fisheries resources, and, delineate the extent of asbestos levels in Clinton Creek, the Forty Mile and Yukon River. The data obtained from this field work were compared and reviewed in light of available literature.

A critical technical review of the scientific literature was also undertaken to assess the effects of asbestos ingestion by humans. This review included personal contacts with internationally recognized expertise to document the most current state-of-the-art concensus regarding human health effects.

The results and findings of this work are presented in the following sections.

2.0 SUMMARY OF ASBESTOS RELATED STUDIES

2.1 Fisheries Assessment

Assessment of impacts of asbestos mining on fish populations in Clinton Creek were conducted using appropriate techniques including electro-shocking, beach seining and minnow trapping. Analysis of resultant data revealed that all sections of Clinton Creek provided suitable habitat and were utilized by healthy, representative fish populations. Arctic grayling, juvenile chinook salmon and sculpins were sampled in Clinton Creek. Fish distribution was governed by habitat characteristics and food availability. Large numbers of grayling inhabited upper Clinton Creek, below the outlet of Hudgeon Lake. This section supported a large biomass of invertebrate drift organisms and represented optimal stream habitat.

Detrimental impacts on fishery resources were observed in a 0.5 kilometer section immediately downstream of the mined area. In this section, outwash of waste rock destabilized the streambed and reduced fish habitat.

Asbestos toxicity levels have not been established for fish, and adverse effects have not been observed in long term experimentation. Asbestos fibers do bioaccumulate in fish (kidney, muscle) and aquatic invertebrate tissue, however the significance has not been determined.

Asbestos toxicity was not experimentally assessed in the present study, and no information was available in the literature to indicate that asbestos toxicity contributes to loss of habitat. Therefore it was concluded that physical alienation (destabilization, siltation, etc.), rather than asbestos toxicity was the apparent reason for loss of fish habitat.

2.2 Asbestos Fiber Levels in Water

The water sampling program established that asbestos fiber concentrations in Clinton Creek increased as flows pass the waste and tailings dumps. Clinton Creek asbestos fiber loads were not carried into the Forty Mile River or downstream to the Yukon River; however, the input from Clinton Creek was masked by a large dilution factor and the naturally high fiber concentrations (from the erosion of metamorphic geology) of the Forty Mile and Yukon Rivers.

Fiber loading in Clinton Creek decreased from 1978 to 1980. Stabilization of waste and tailings dumps, construction of weirs to impede erosion, and lower annual water discharge may have contributed to this trend.

Fiber concentrations at Clinton Creek were relatively high and of the same magnitude as those observed in drinking water supplies of other asbestos mining or deposit areas. Clinton Creek's fiber load was similar to that of lower British Columbia watersheds with comparative geology.

Fiber lengths at Clinton Creek were longer on the average than those found at other locations across Canada. This was likely related to the close proximity of easily eroded material containing large amounts of asbestos fibers. The biological significance of fiber length has not been documented.

2.3 Ingested Asbestos, Literature Review

A review and critical assessment of available literature revealed that the hazards of orally ingested asbestos fibers are not thoroughly understood. Studies have been conducted with experimental animals that demonstrate cytotoxic effects of asbestos ingestion. Attempts

have also been made to correlate asbestos fiber concentrations in potable water with increases in gastrointestinal cancer, but were generally inconclusive.

The estimated risk factor, calculated by the United States E.P.A. using occupational exposure data related to inhalation and subsequent ingestion of fibers, was minimal. One excess cancer was expected per 100,000 people exposed to 0.3×10^6 fibers per litre at a level of 2 litres per day over a 70 year lifetime. However, the level of confidence in this estimate is low and severely limits any accurate projections regarding the level of asbestos in water that will produce a specified risk.

Recognized scientific expertise (Health and Welfare Canada, United States Environmental Protection Agency) indicated that insufficient information existed upon which to base a sound conclusion regarding the physiological effects of asbestos ingestion.

3.0 FISHERIES IMPACT ASSESSMENT

3.1 Introduction

During September 1980, a biological assessment of the Clinton Creek watershed (Figure 1) was undertaken. The objective of this survey was to inventory the indigenous fish stocks and critically evaluate the influence of mining activities on the instream habitat and fishery resource.

For most fish species within the study area, specific life history, distribution and abundance data was very limited. To augment the existing information (EPS Report 1975), an intensive one week sampling program was designed to delineate the late summer-fall fishery resource and their instream distribution.

3.2 Methods

3.2.1 Site Reconnaissance

A site reconnaissance was conducted September 04, 1980 to delineate sampling locations within the study area. Clinton Creek from Hudgeon Lake to Forty Mile River was subdivided into six sections (Figure 2), and sampled over a six day period (September 05-10, 1980). Table 1 describes the instream habitat for each of these sections.

3.2.2 Minnow Trapping

Minnow Traps (Gee Improved Minnow Traps) (Photo 5) were utilized as presence/absence indicators of rearing fish. Eight areas of Clinton Creek (Figure 2) were sampled for six days with three traps per site.

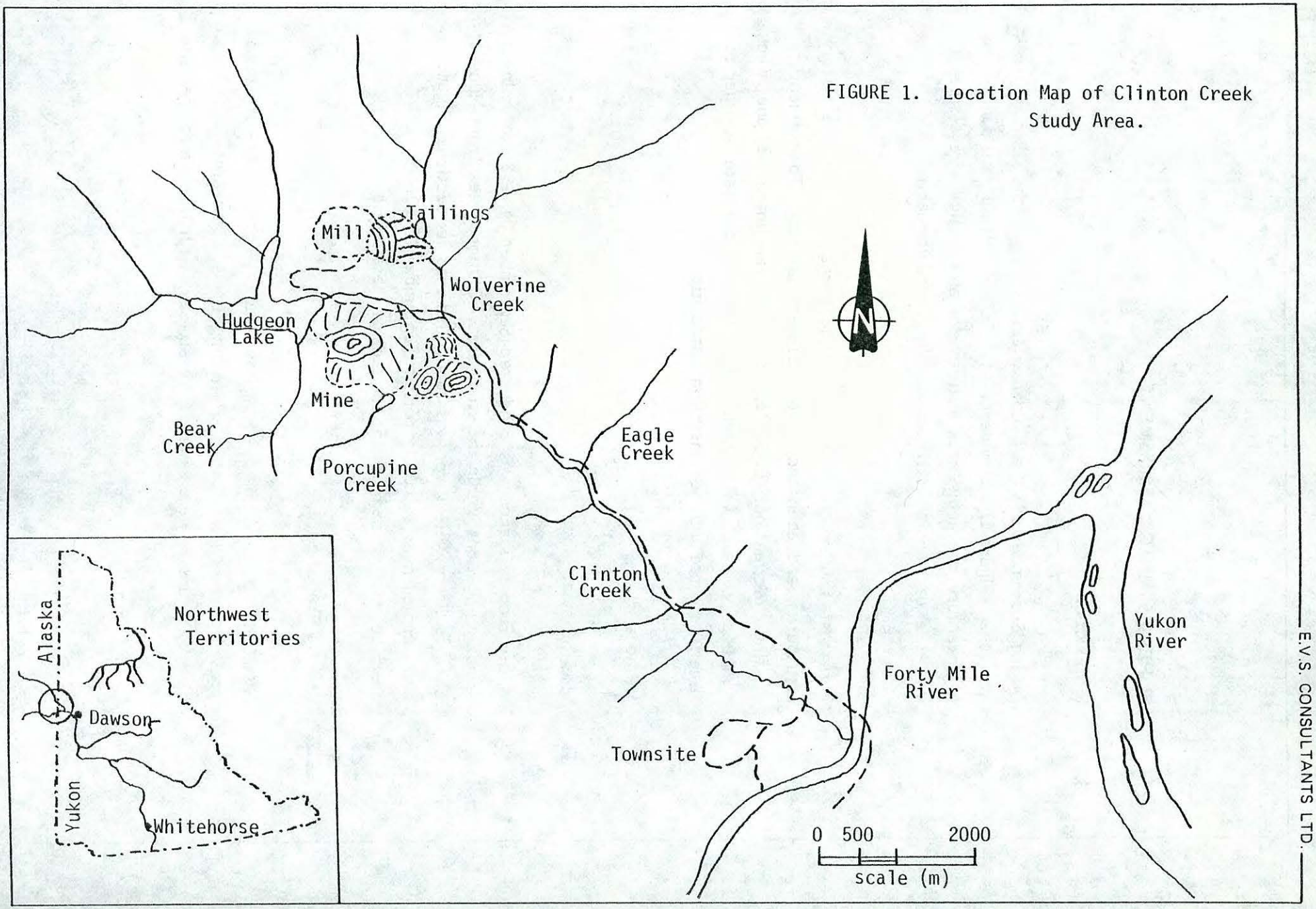


FIGURE 1. Location Map of Clinton Creek Study Area.

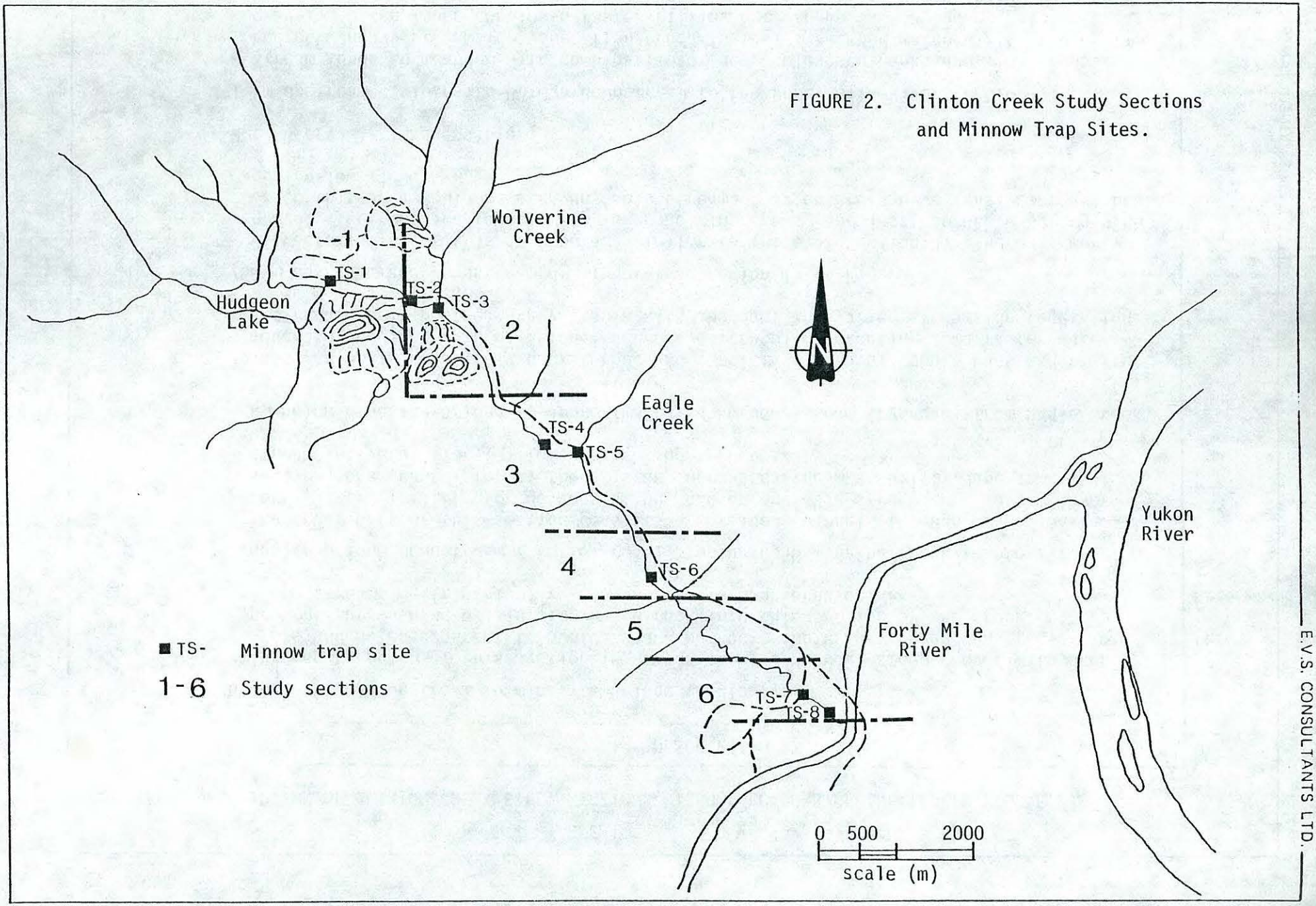


FIGURE 2. Clinton Creek Study Sections and Minnow Trap Sites.

TABLE 1

HABITAT DESCRIPTION OF CLINTON CREEK STUDY SECTIONS, 1980 (SECTIONS DELINEATED IN FIGURE 2)

SECTION	DESCRIPTION
1	Hudgeon Lake downstream to Minesite Bridge (Photo 1): - The upper region of this section is dominated by a narrow, steep canyon with deep slots and holes adjacent to boulders and bedrock. Weirs have been constructed to prevent the washing of slumping waste rock into this section of the creek. There is no streamside (riparian) vegetation due to bank erosion.
2	Minesite Bridge downstream 2 km (by road), including Wolverine Creek (Photo 2): - The upper part of this section consists of braided channels through washed waste rock. There is little or no vegetation, and an unstable streambed. In the lower section, one channel forms; there is an increased stream stability, and some streamside vegetation (willows, brush and spruce trees).
3	2 km below Minesite Bridge to approximately 2 km downstream (by road) from Eagle Creek (Photo 3): - This region is relatively undisturbed and consists of gravel/cobble runs and riffles, moderate gradient with occasional bedrock outcroppings creating some faster water and rock debris. Stream very stable with abundant and varied streamside vegetation.
4	750 m upstream and downstream of minnow trap region TS-6 (Figure 2): - Characteristics of this section are similar to those of Section 3. There is more gravel, the runs are longer with fewer holding areas, and less bedrock. During high water this area would have an unstable streambed as observed by extensive gravel beds during low flow.
5	Not observed - inaccessible
6	1 km upstream of Townsite Bridge downstream to the Forty Mile River (Photo 4): - Stream tends to meander with combination of deep holes, cutbanks and small runs. No bedrock, heavy streamside vegetation predominates, streambed material is sand or fine gravel. Often loose cobble in faster riffles between pools. Abundant holding areas, root wads and log jams. Stream bank and bottom become quite unstable towards the confluence with Forty Mile River.

PHOTO 1. Section 1 of Clinton Creek, looking upstream towards Hudgeon Lake. Note boulder weirs for flow control. September 1980.

PHOTO 2. Section 2 of Clinton Creek, flowing downstream through braided channels of waste rock. September 1980.

PHOTO 3. Section 3 of Clinton Creek, looking downstream. September 1980.

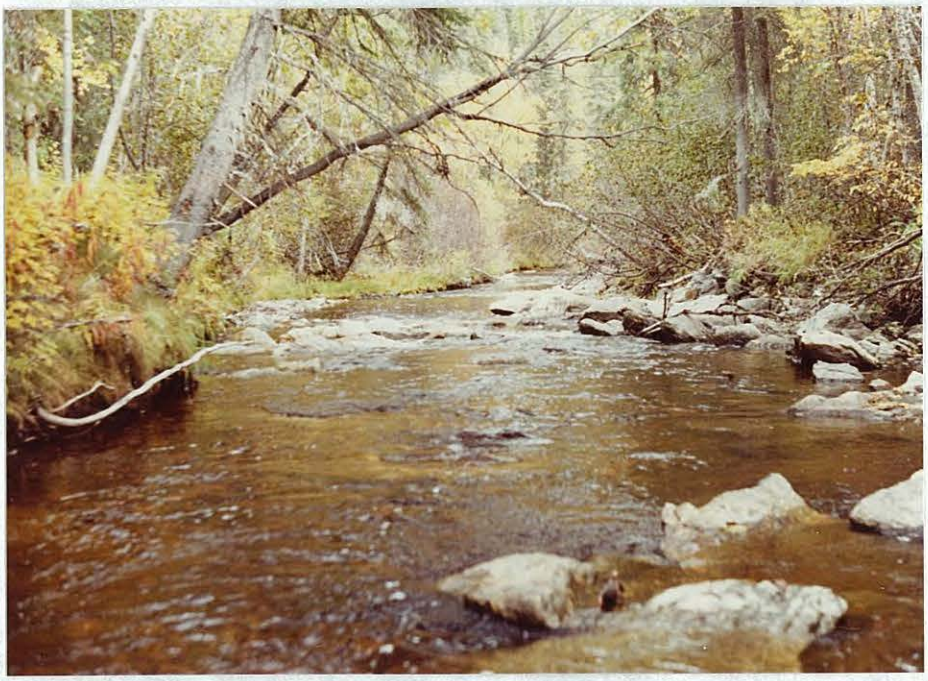


PHOTO 4. Section 6 of Clinton Creek, looking downstream. September 1980.

The traps, baited with canned salmon, were fished for 24 hour periods, and checked daily at approximately 0900 hrs. All fish collected were anaesthetized with MS-222, measured for length (mm), scale sampled, and released upon recovery. Water temperature (^{o}C) was recorded for each sampling period and site.

3.2.3 Electroshocking

A Smith-Root Type VII Electro-Fisher (Photo 6) was utilized to obtain additional data on fish abundance and distribution within Clinton and Wolverine Creeks (Figure 3). All fish collected, with the exception of three Arctic grayling, were measured for length, scale sampled and released. Three grayling were sacrificed and their stomachs excised for diet analysis.

3.2.4 Gillnetting

Gillnets (mesh sizes of 2.5, 6.4 and 10 cm) were used at the outlet of Hudgeon Lake (Figure 3) for sampling fish populations. The nets were checked at regular intervals over a three day period, and captured fish were measured for length, scale sampled and sacrificed for diet analysis.

3.2.5 Two-Way Weir

A two-way weir (Photos 7 & 8) was installed approximately 30 m upstream of the Clinton Creek and Forty Mile River confluence (Figure 3) to determine the movement of fish utilizing Clinton Creek during the sampling period. The weir, equipped with upstream and downstream catch boxes, was constructed with ¼ inch galvanized mesh and reinforcing bars. It was fished for five days (September 06-10, 1980) and

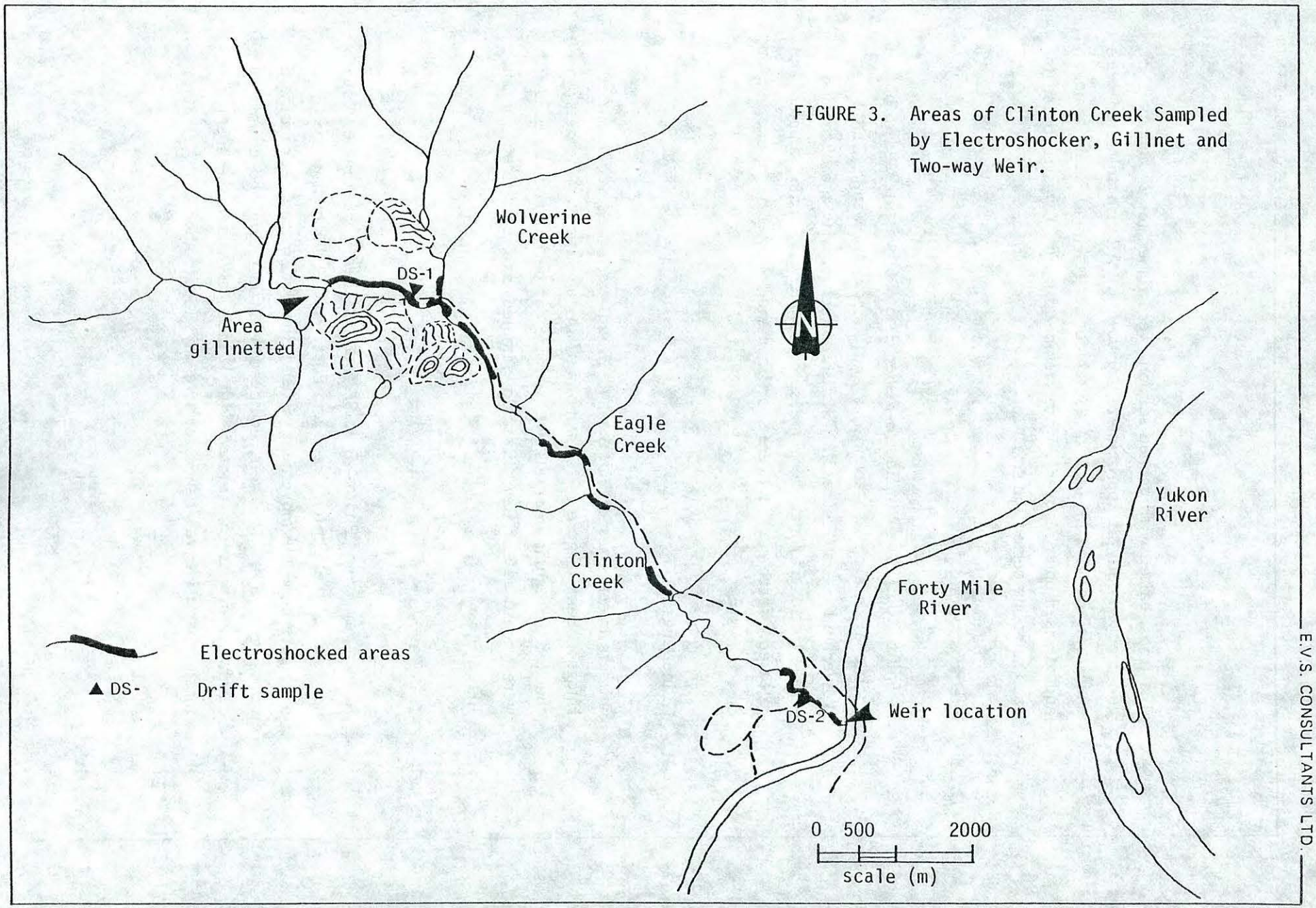


FIGURE 3. Areas of Clinton Creek Sampled by Electroshocker, Gillnet and Two-way Weir.

PHOTO 5. Minnow traps utilized as presence/absence indcators of resident fish.

PHOTO 6. Electroshocking utilized to delineate fish abundance and distribution.

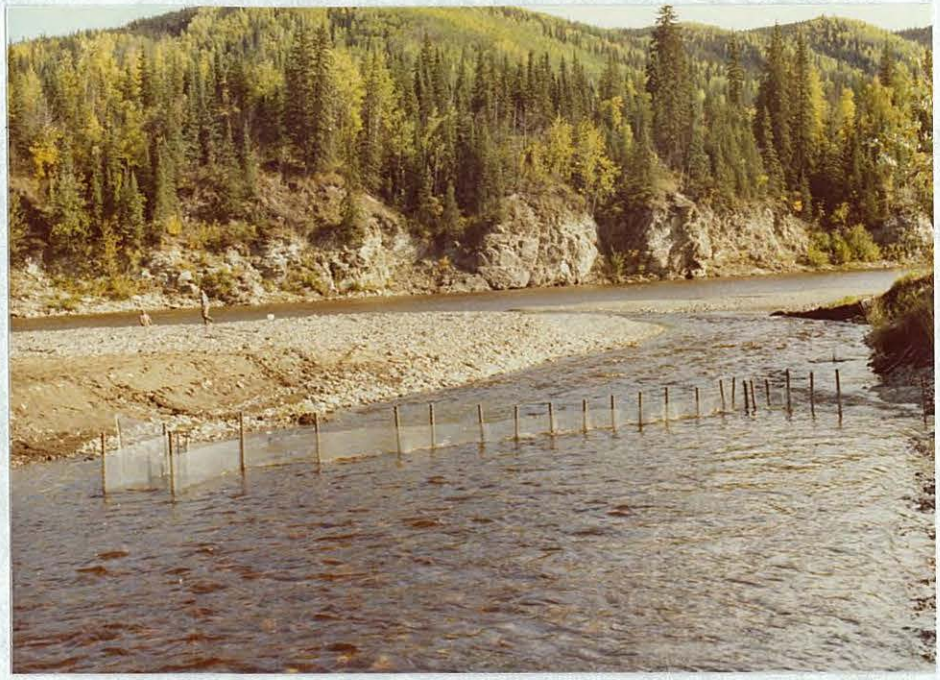


PHOTO 7. Two-way weir on Clinton Creek at the confluence with the Forty Mile River.

PHOTO 8. Downstream trap of the two-way weir.

monitored three times daily. Water temperature (^{o}C) and relative water level were recorded at each sampling period. All fish trapped were anaesthesized, measured for length, scale sampled and released.

3.2.6 Beach Seining

Beach seining (Photo 9), using a 10 m seine net with 0.32 mm mesh, was limited to the Forty Mile River, immediately adjacent to the confluence with Clinton Creek. The physical characteristics of Clinton Creek were not conducive to seining as a method of sampling. All fish collected were anaesthesized, measured for length, scale sampled and released.

3.2.7 Invertebrate Drift Samples

Invertebrate drift samples were collected to estimate the relative productivity of Clinton Creek, and the amount of food available to resident fish. Two sampling sites (Figure 3) were selected: (1) the upper sample site (DS-1) was upstream of the Minesite Bridge, below the canyon at the lake outlet; and (2) the lower sample site (DS-2) was upstream of the Townsite Bridge.

The samples were collected with a surber sampler set in midstream and left for a period of 14 hours. The samples were stored in 10% formalin, and upon returning to the lab were examined and qualitatively sorted using a binocular microscope.

3.2.8 Diet (stomach) Analysis

To compare invertebrate drift with feeding preference of fish in Clinton Creek and Hudgeon Lake, stomachs of 6 fish were collected during the field study. Following capture the fish stomachs were excised, stored in 10% formalin and examined similar to the drift

samples. The percent compositon of diet was identified to Order and a percent stomach fullness estimated for each sample.

3.3 Results

3.3.1 Fish Catches

3.3.1.1 Minnow Trapping

Minnow traps were moderately successful in catching resident fish, with three species (chinook salmon, Arctic grayling and slimy sculpin) collected from minnow trap sites 2 to 7 (Table 2). Trap sites 1 and 8 were void of fish catches, indicating either low fish abundance or poor fishing success at these trapping sites during the sampling period. A complete summary of minnow trap catches is tabulated in Appendix I.

3.3.1.2 Electroshocking

Electroshocking was effective for delineating fish distribution within Clinton Creek. Table 3 summarizes the catch data presented in Appendix II. Chinook salmon juveniles (Photo 10) appeared to be evenly distributed throughout Clinton Creek, whereas grayling (Photo 11) were heavily concentrated in the mid and lower reaches of Section 1.

3.3.1.3 Gillnetting

Gillnetting in Hudgeon Lake did not result in large catches (Table 4). Only three grayling specimens (284, 310 and 360 mm) were taken in 66 hours of fishing, and all fish were caught in the 6.4 cm mesh. Water temperatures ranged from 7.0 to 8.0^{o}C. The grayling were in very good condition, with a large amount of fatty tisue in the body cavity, and no external evidence of disease (i.e. no lesions or fungus) or obvious internal parasites.

PHOTO 9. Beach seining in the Forty Mile River near the confluence with Clinton Creek.

PHOTO 10. Juvenile chinook salmon utilizing Clinton Creek, September 1980.

PHOTO 11. Arctic grayling captured in Clinton Creek, September 1980.

TABLE 2

SUMMARY* OF MINNOW TRAP CATCHES FROM CLINTON CREEK, SEPTEMBER 05-10, 1980

TRAP SITES**	TEMPERATURE RANGE (°C)	SPECIES		
		CHINOOK	GRAYLING	SCULPIN
TS-1	7.0 - 8.0	0	0	0
TS-2	7.0 - 8.0	4	2	1
TS-3	5.5 - 7.0	6	1	0
TS-4	5.0 - 7.0	2	0	0
TS-5	3.5 - 6.5	2	1	0
TS-6	3.5 - 6.5	0	1	0
TS-7	3.5 - 6.5	4	1	0
TS-8	4.0 - 6.0	0	0	0

*Summarized from Appendix I
**Trap Sites from Figure 2.

TABLE 3

SUMMARY* OF ELECTROSHOCKING CATCHES FROM CLINTON CREEK, SEPTEMBER 05-10, 1980

SAMPLING SECTION**	CHINOOK	GRAYLING
1	4	34
2	7	5
3	3	2
4	2	4
6	7	1

*Summarized from Appendix II
**Sampling sections from Figure 3.

TABLE 4
GILLNETTING RESULTS FROM HUDGEON LAKE

DATE	MESH (cm)	TEMP. (°C)	HOURS FISHED	SPECIES CHNK	GRAY	WTF	SUCK	COTT
8/09	10							
	6.4	7.0	19		3 (360 mm)			
	2.5				(284)			
9/09	10				(310)			
	6.4	7.0	23					
	2.5							
10/09	10							
	6.4	8.0	24					
	2.5							
				$\bar{x}$	318.00 mm			
				S.D.	38.63			
				n	3			

TABLE 5
FISH CATCHES FROM TWO-WAY WEIR INSTALLED IN LOWER CLINTON CREEK

DATE	TIME (h)	TEMP. (°C)	TRAP	SPECIES CHNK	GRAY	WTF	SUCK	COTT
6/09	0820	4.0	upstream		1 (61 mm)			
	1600	4.0						
	2200	5.0	upstream		1 (172)			
7/09	0800	4.0						
	1700	4.0	upstream		1 (66)			
	2130	5.0						
8/09	0815	4.0						
	1230	5.0						
	2130	6.0						
9/09	0815	4.5						
	1305	6.5						
	2130	7.0						
10/09	0820	6.0						
	1140	7.0						
	Demobilized							
				$\bar{x}$	99.67 mm			
				S.D.	62.69			
				n	3			

CHNK - Chinook
GRAY - Grayling
WTF - Whitefish
SUCK - Sucker
COTT - Sculpin

3.3.1.4 Two-Way Weir

Three grayling (61, 66 and 172 mm) were captured in the upstream component of the two-way weir (Table 5). The downstream trap did not operate efficiently due to the accumulation of leaves on the fence mesh and an unstable stream bed.

The water temperature varied from 4.0 to 7.0°C, and the water level fluctuated by less than an inch in height over the sampling period.

3.3.1.5 Beach Seining

A total of six seine hauls over two days were completed in the Forty Mile River. Grayling, whitefish, suckers and sculpins were caught. Length and catch data are presented in Table 6.

3.3.2 Age-Length Analysis

Scale samples were taken from chinook, whitefish and grayling collected by the various sampling methods (Appendix III).

All chinook and whitefish were age 0+, that is, in their first year of growth. Length frequency graphs for both species are plotted in Figure 4 and 5, respectively. The mean length of chinook juveniles was 84.2 mm (SD = 5.94 mm), and of whitefish, 59.0 mm (SD = 3.74 mm).

Grayling ranged in age from 0+ to 6 years. The age frequency graph for grayling (Figure 6) shows a normal distribution of age classes; that is, the number of individuals of a given age class decrease with increasing age. Approximately 70% of the sampled grayling were less than 3 years

TABLE 6

BEACH SEINING RESULTS - CONFLUENCE OF CLINTON CREEK AND FORTY MILE RIVER

DATE	TEMP. (°C)	No. SEINE HAULS	SPECIES			
			GRAYLING	WHITEFISH	SUCKERS	COTTIDS
5/09	5.5-6.5	4	56mm 72	59 60	325	52 30 30
9/09	6.5	2	75 41 57 62	63 54	420 308	30 25 27 28 24
		$\bar{x}$	60.5	59.0	351.0	30.8
		S.D.	12.30	3.74	60.36	8.89
		n	6	4	3	8

TABLE 7

RELATIVE COMPOSITION OF THE DRIFT SAMPLES COLLECTED FROM CLINTON CREEK

SAMPLE NO.	DATE	SITE	HOURS FISHED	DRIFT COMPOSITION
1	09/09	Minesite Br. DS-1	17 hr.	-95% Daphnia -5% Chironomid puppae -some filamentous algae -lots of debris
2	10/09	Townsite Br. DS-2	16 hr.	-few Daphnia -few Diptera larvae -lots of debris

Figure 4. Length frequency distribution of chinook salmon fry sampled from Clinton Creek.

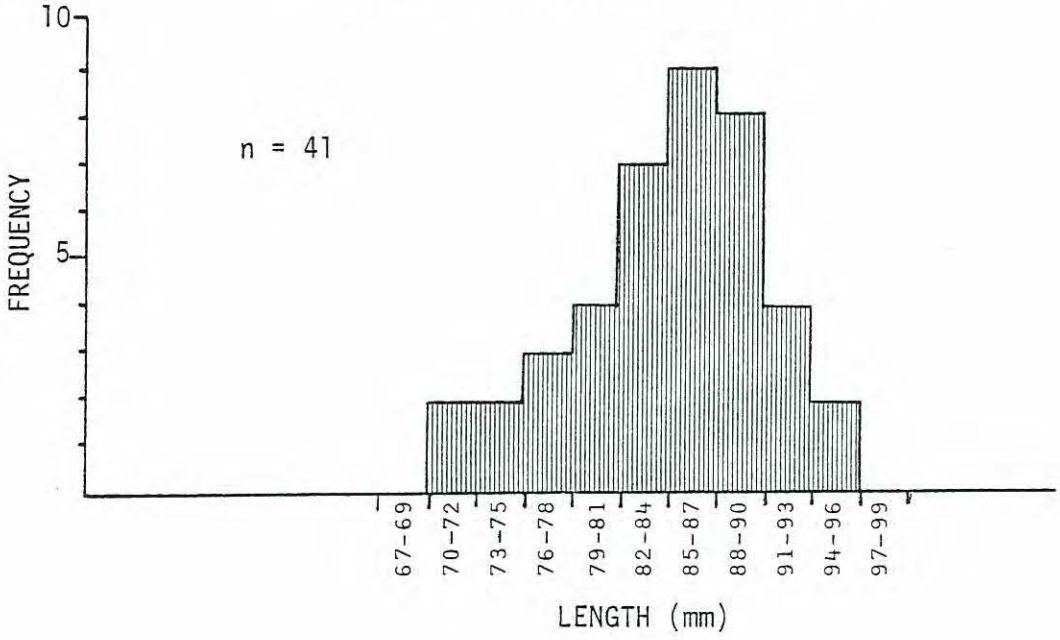


Figure 5. Length frequency distribution of round whitefish juveniles sampled at Clinton Creek/Forty Mile River confluence.

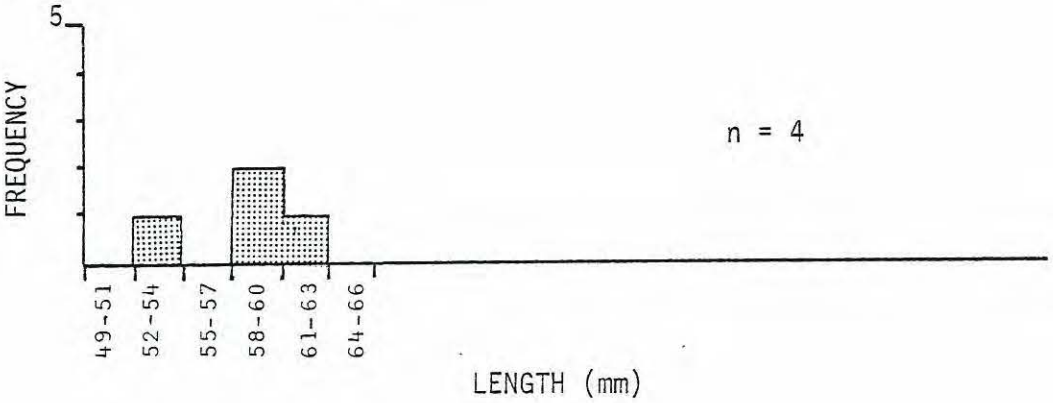
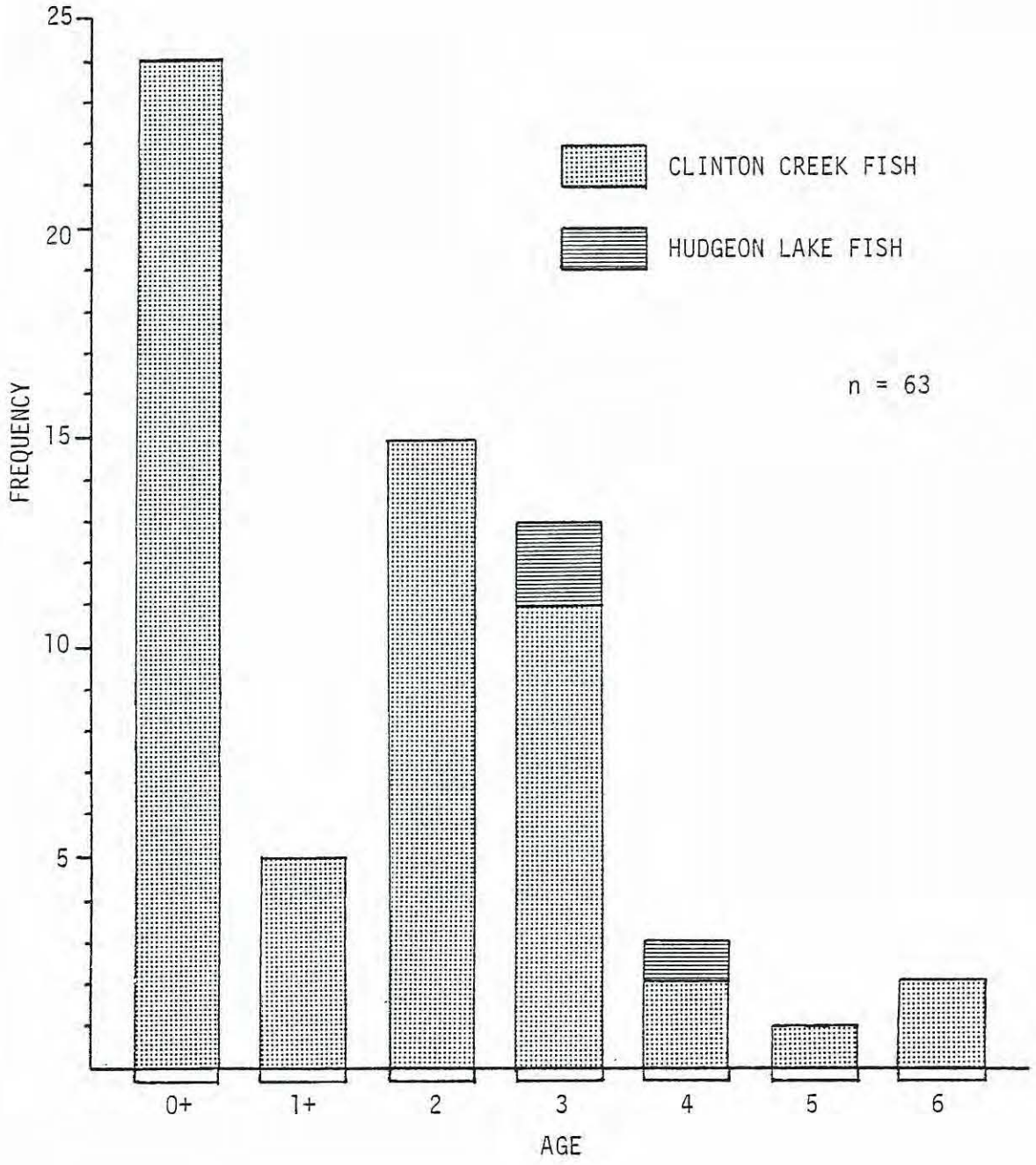


Figure 6. Age frequency distribution of Arctic grayling sampled from Clinton Creek.



of age. Figure 7 summarizes the length frequency and age composition of grayling. Definite size classes are evident for the majority of aged grayling. The length distribution of younger grayling corresponds reasonably well to the individual age classes. The lake grayling (ages 3 and 4) are larger compared to similar aged river grayling; thus the lake environment is clearly more conducive to greater growth for grayling.

3.3.3 Invertebrate Drift Samples

Drift samples from the upper section of Clinton Creek (Table 7) contained a significant abundance of invertebrates, especially Daphnia sp. The lower segments of Clinton Creek, in the vicinity of the Townsite Bridge, were relatively void of stream invertebrates.

3.3.4 Diet (stomach) Analysis

The diet composition of the six grayling from Hudgeon Lake and Clinton Creek is summarized in Table 8. The lake grayling appeared to be feeding primarily on insect larvae and their stomachs were approximately 20% full. The stomachs of the stream grayling (caught in Section 1) were distended (approximately 100% full), and overflowing with Daphnia sp.

3.4 Discussion

3.4.1 Fish Presence and Utilization of Clinton Creek

Previous studies on northern watersheds (Bryan et al. 1973; Steigenberger et al. 1974; Walker et al. 1974; Steigenberger et al. 1975; Brown et al. 1976; and Walker 1976) have shown that small streams similar to Clinton Creek provide important spawning, rearing and overwintering

Figure 7. Length frequency distribution and age composition of Arctic grayling sampled from Clinton Creek.

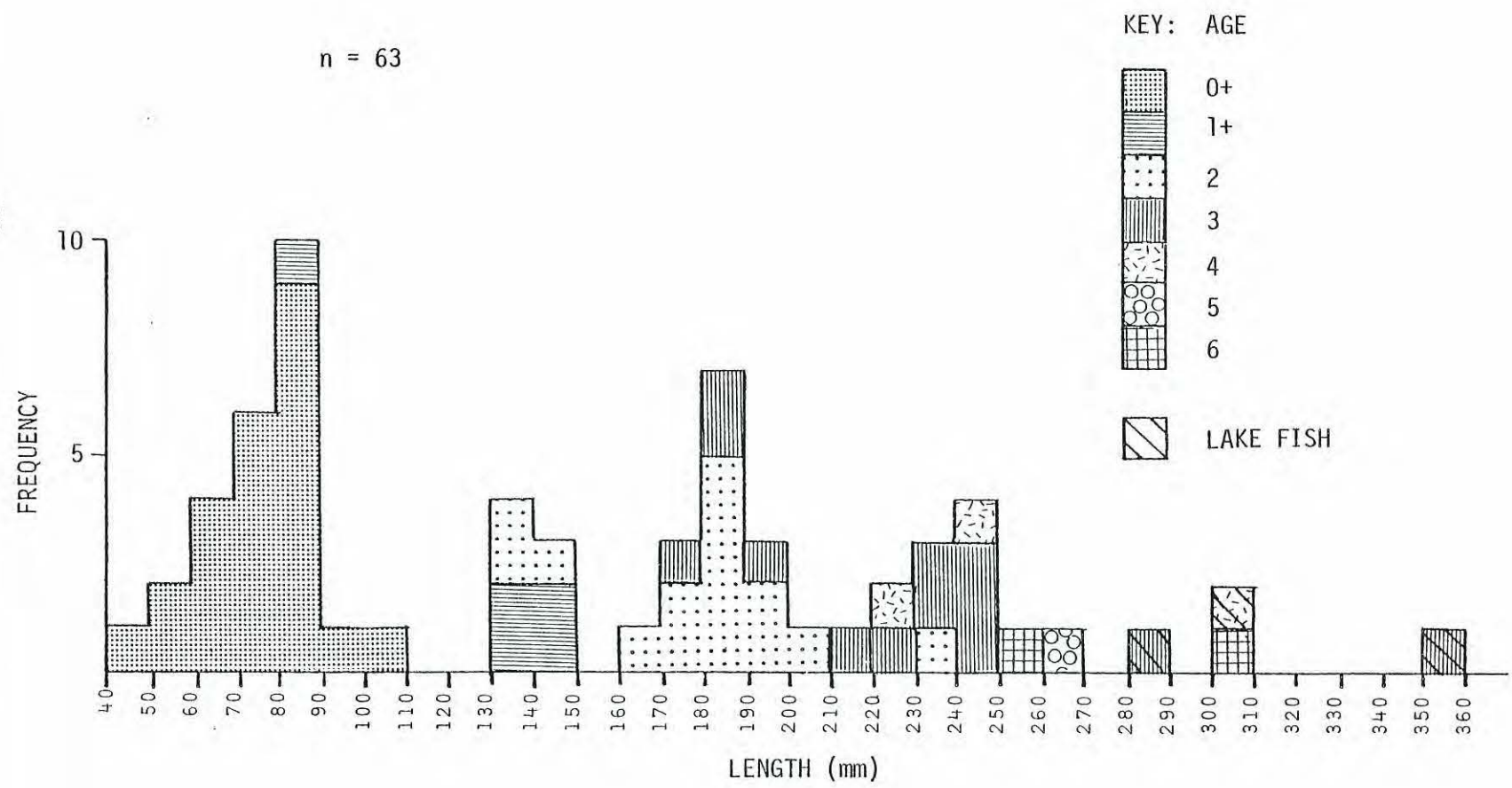


TABLE 8

DIET COMPOSITION OF SIX ARCTIC GRAYLING FROM HUDGEON LAKE AND CLINTON CREEK. SEPTEMBER 1980

ENVIRON	SECTION	CAPTURE METHOD	FORK LENGTH (mm)	EST. % FULLNESS	PERCENT COMPOSITION: DIET ORDERS						
					DAPH	TRIC	DIPT	HYME	EPHEM	COLEO	ODON
Lake	outlet	GN	284	20	<1	8	8		80		
Lake	outlet	GN	310	20	<1	3	3		80	3	
Lake	outlet	GN	360	20		4	3		70	3	20
Stream	1	ES	250	100	95			5			
Stream	1	ES	308	100	95			3		2	
Stream	1	ES	270	100	85	5	7	3			

Capture Method

GN = Gillnetting
ES = Electroshocking

Diet Orders

DAPH = Daphnia
TRIC = Tricoptera (Caddisflies)
DIPT = Diptera (Flies)
HYME = Hymenoptera (Ants)
EPHEM = Ephemeroptera (Mayflies)
COLEO = Coleoptera (Beetles)
ODON = Odonata (Dragonflies)

habitat for fish. These small tributaries are often utilized seasonally by fishes indigenous to larger systems such as the Forty Mile River. Fish species recorded in the upper Yukon river drainage, and their spawning periods, are listed in Table 9.

During the present study (September 1980), grayling, juvenile chinook salmon and sculpins were the three species found to be inhabiting Clinton Creek. This compositon was similar to other creeks studied on various tributaries of the Yukon and Porcupine River watersheds (Bryan et al. 1973; Steigenberger et al. 1974; Walker et al. 1974; Steigenberger et al. 1975; and Brown et al. 1976).

A study conducted on Clinton Creek during the summer of 1975 (EPS Report 1975) observed a more diverse fishery compared to the present survey. Besides grayling, sculpins and chinook juveniles, longnosed suckers, lake and round whitefish, were recorded. The seasonal difference in timing of the two studies would explain the discrepency in fish composition. With the approach of winter, these species would be expected to migrate out of Clinton Creek. Seining at the confluence of Clinton Creek and the Forty Mile River confirmed the presence of these species in the local vicinity, with the exception of the lake whitefish.

In general, adult grayling enter small streams similar to Clinton Creek to spawn following spring break-up, and leave after spawning (Figure 8). The subsequent fry, emerging in late June to early July, as well as juvenile and immature upstream migrants, will remain throughout summer and utilize the stream rearing habitat until freeze-up. Downstream migration in the late fall, to the system of origin, is initiated by the declining water temperatures (Reed 1964; Chapman & Bjornn 1969; McPhail & Lindsey 1970; Craig & Poulin 1975; and Stuart & Chislett 1979).

TABLE 9

FISH SPECIES RECORDED IN THE UPPER YUKON RIVER DRAINAGE
(FROM BROWN ET AL., 1976)

Inconnu	*Stenodus leucichthys*	(Family Coregonidae)
Humpback whitefish	*Coregonus clupeaformis*	(" ")
Broad whitefish	*Coregonus nasus*	(" ")
Least cisco	*Coregonus sardinella*	(" ")
Round whitefish	*Prosopium cylindraceum*	(" ")
Arctic grayling	*Thymallus arcticus*	(Family Thymallidae)
Lake trout	*Salvelinus namaycush*	(Family Salmonidae)
Chinook Salmon	*Oncorhynchus tshawytscha*	(" ")
Chum salmon	*Oncorhynchus keta*	(" ")
Coho salmon	*Oncorhynchus kisutch*	(" ")
Rainbow trout	*Salmo gairdneri*	(" ")
Cutthroat trout	*Salmo clarkii*	(" ")
Northern pike	*Esox lucius*	(Family Exocidae)
Longnose sucker	*Catastomus catastomus*	(Family Catastomidae)
Burbot	*Lota lota*	(Family Gadidae)
Slimy sculpin	*Cottus cognatus*	(Family Cottidae)
Arctic lamprey	*Lampetra japonica*	(Family Petromyzontidae)
Lake chub	*Couesius plumbeus*	(Family Cyprinidae)

SPAWNING PERIODS

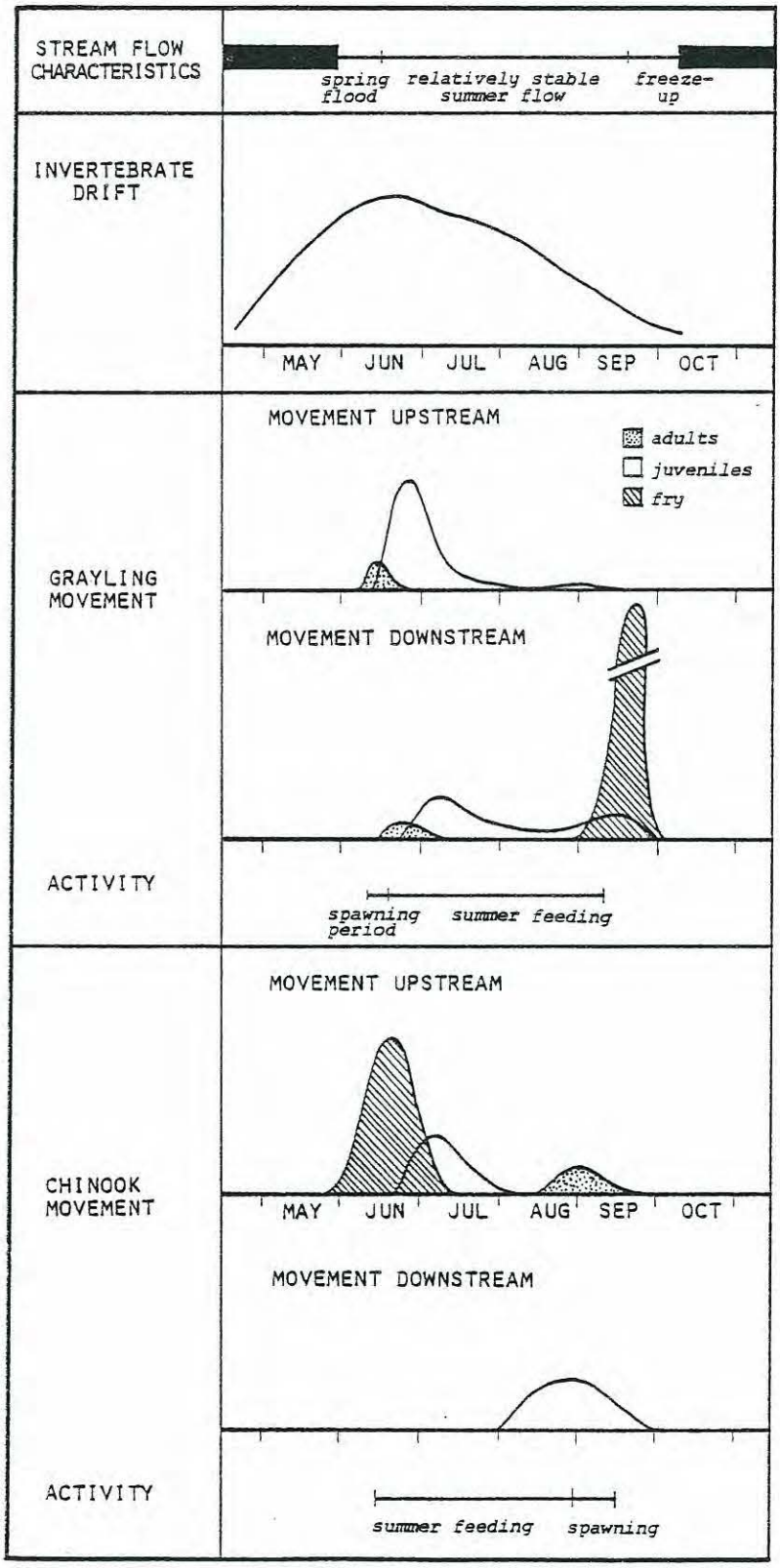
SPRING-SUMMER

Spawning species of fish	Spawning period
Thymallus arcticus	May - mid-June
Esox lucius	Spring
Catastomus catastomus	Spring thaw
Cottus cognatus	May
Salmo clarkii (planted)	Spring
Salmo gairdneri (planted)	Spring
Couesius plumbeus (if present)	May
Lampetra japonica	May - July

AUTUMN-WINTER

Prosopium cylindraceum	Autumn
Coregonus clupeaformis	Late summer - early autumn
Coregonus nasus	Late summer - early autumn
Coregonus sardinella	Autumn
Lota lota	Winter (Feb.-Mar.)
Salvelinus namaycush	July - October
Stenodus leucichthys (if present)	September - early October
Oncorhynchus tshawytscha	August - early September
Oncorhynchus keta (if present)	September - October
Oncorhynchus kisutch (planted)	October - November

Figure 8. Schematic diagram of stream flow characteristics, invertebrate drift, and movements of grayling and chinook in small northern streams (modified from Craig and Poulin, 1975).



Chinook salmon fry also appear to utilize these small streams as rearing habitat (Figure 8). Although they may emerge from the spawning gravel of a larger stream or river, they will migrate up smaller streams to rear, possibly attracted by the abundant habitat cover and food, not available in the larger systems (Walker 1976; Olmsted et al. 1980).

Many of the small streams freeze to the bottom during a typical winter, but any open water, deep unfrozen pools or spring-fed areas will provide overwintering habitat for small resident populations (Chapman & Bjornn 1969; Steigenberger et al. 1974).

Within Clinton Creek, the distribution and abundance of grayling and juvenile chinook was readily explained by available rearing and feeding habitat. Approximately two-thirds of the grayling were found in Section 1. The habitat of this section consisted of a small canyon in which the stream exhibited torrential characteristcs. Grayling of all sizes and ages, as well as a few juvenile chinook, utilized the small pockets and pools formed beside large boulders, along rock walls and below small falls. This canyon does not appear to hamper fish migrations except during periods of low flow. This section supported a relatively abundant fish population for two reasons: (1) the abundant instream cover habitat, and (2) the large biomass of food organisms, observed by correlating the overflowing stomach contents of Daphnia and the invertebrate drift collections.

Wolverine Creek, a tributary of Clinton Creek, did not support a fishery during the sampling period. The streambed consisted of washed tailings from the mine operation, and it has experienced wildly fluctuating flows which have destroyed any fish habitat formerly present. Further, the road culverts impede fish passage into Wolverine Creek.

Clinton Creek downstream of Wolverine Creek, has experienced little obvious disturbance from upstream mining activities. However, relatively few fish inhabited the lower sections of the stream. Low catches possibly reflect poor seasonal cover habitat and the lack of food organisms, shown by the drift collection. It is likely that the food drifting from the lake was depleted by fish predation in the upper sections of Clinton Creek.

From Wolverine Creek to the confluence with the Forty Mile River, fry and juvenile grayling, and chinook fry comprised the entire population utilizing these sections. The fish occupied deeper pools or slow runs, and were closely associated with rock piles, boulder accumulations and small instream log jams. Most individuals rose out of boulder substrate when stunned by the electroshocker. In Section 6, chinook fry were utilizing deeply undercut banks in the absence of other cover habitat.

Hudgeon Lake supported a small grayling population. During periods of median to high flow, it was possible for fish to move between the lake and Clinton Creek. The lake grayling were feeding primarily upon insect larvae/nymphs, which as noted above, differed from the stream grayling who were consuming an inordinate number of lake-produced cladocerans (Daphnia). This difference in feeding preference/strategy was related to the variation in density of prey items within the lake and creek. The relative concentration of cladocerans was greatest at the lake outlet due to a flushing effect of the lake, compounded with the constricted narrows the water must pass through. This produced an extremely high density of cladocerans in the stream drift. However within Hudgeon Lake, the relative concentration of cladocerans to the total water volume would be low, thus lake grayling predation upon larger prey items (insect larvae/nymphs) would require less effort for energy gain. The larger size of lake grayling compared to similar aged stream grayling clearly shows the high productivity of the lake environment.

3.4.2 Effect of Mining Activities on Clinton Creek Fisheries Resources

Any activity associated with a watercourse, such as mining, logging, road construction, etc., can alter the 'normal' biotic/abiotic characteristics of the aquatic environment. For example, changes may occur in water flow, temperature, and addition of contaminants, which all interact to influence instream habitat and the diversity and density of the resident fishery resource. However, not all activities and the resultant changes are detrimental.

For example, the activities of mining in the Clinton Creek watershed affected fish habitat only in areas closely associated with the slumping waste rock pile. Erosion of waste rock has destroyed favourable habitat in the region of the Minesite Bridge and Wolverine Creek. Washed materials have accumulated, causing a shallower streambed, less cover and loss of food organism habitat. However, lower Clinton Creek remained relatively unaffected by upstream mining activities. Although the present study found a limited fishery in the lower sections, suitable habitat was abundant and food may be the limiting factor for fish absence during late summer.

Formation of Hudgeon Lake has removed stream habitat that may have supported grayling and chinook salmon fry. However, the lake appears to supply additional, productive habitat to enhance and supplement grayling stocks. At present, Hudgeon Lake is not heavily utilized by fish, but an abundance of food, in the form of zooplankton, is carried downstream where it is an important component in the diets of fish inhabiting Section 1 of Clinton Creek.

3.5 Conclusion

The present biological assessment found that Clinton Creek provides good spawning and rearing habitat for grayling and rearing habitat for juvenile chinook salmon. No adult salmon were observed utilizing the creek.

Although the stream habitat was clearly altered in the immediate vicinity of the waste piles on Clinton and Wolverine Creeks, the sections of upper Clinton Creek support a healthy population of grayling and juvenile chinook, which thrive on favourable stream habitat and the abundant food originating in Hudgeon Lake. The formation of Hudgeon Lake has created a unique habitat that has enhanced the grayling population in the area.

4.0 BIOLOGICAL EFFECTS OF ASBESTOS FIBERS ON AQUATIC ORGANISMS

Information regarding the biological effects of asbestos fibers on aquatic organisms is very limited.

Studies have been completed on Clinton Creek in attempts to ascertain impacts of asbestos mining on the aquatic community. The Environmental Protection Service (1977) conducted a series of bioassays using juvenile coho salmon in attempts to determine possible effects of waterborne chrysotile asbestos fibers. Water for the tests was taken from the mine pumphouse at Hudgeon Lake. Enumeration of asbestos fibers revealed approximately 3.0×10^8 fibers/litre. No toxic effects were noted over 16 days at 100% concentration. Subsequent histopathological assessments of gill tissue from experimental fish suggested some damage of gill tissue, but the significance was unknown. During this study, waters from Clinton and Wolverine Creeks were not lethal to juvenile coho salmon over a 96 hour exposure period. Fiber concentration was considered to be high, especially in Wolverine Creek.

A fisheries assessment by the Environmental Protection Service (1977) revealed healthy fish populations at all sites providing sufficient habitat. Concurrent studies on the benthic invertebrate community indicated detrimental effects on numbers and diversity of organisms in the vicinity of the dump toes, which can be related to unstable streambed conditions.

Oxberry et al. (1978) using long term toxicity experimentation found no adverse effects on the survival and condition of fish and invertebrates to continuous exposure of taconite tailings waste (31% amphiboles and

other silicate fibers). The exposed fish included juvenile rainbow trout (Salmo gairdneri), brook char (Salvelinus fontinalis) and yellow perch (Perca flavescens), with representative food organisms such as amphipods (Pontoporeia affinis) and shrimp (Mysis relicta). Further, no effects were observed on the hatching success of rainbow trout or lake char (Salvelinus namayeush) eyed eggs, or on the survival of resultant alevins. In contrast, a study by the Federal Water Pollution Control Administration (1970; cited in Shugar 1979) found that some mortalities resulted when rainbow trout alevins were exposed to taconite waste, and concerns were voiced regarding the possible adverse effects of large quantities of suspended materials on fish spawning, food production, and reduction in light penetration. However, no descriptive data were presented.

The United States Environmental Protection Agency (U.S. EPA) studied bioaccumulation of asbestos fibers in lake trout from Lake Superior. Fibers accumulated in small numbers within kidney tissue, however no accumulation was observed in the muscle tissues. It appeared that asbestos fibers were obtained by trout through the food chain and not directly from the water (P. Cook, U.S. EPA; pers. comm.).

Preliminary findings of research conducted on the Yukon River (Metsker 1980) has indicated bioaccumulation of asbestos fibers in liver and kidney tissues of resident fish, approximately 100 times greater concentration that similar samples from Lake Superior. The implications of the fibers in liver and kidney of fish have not been evaluated.

Halsband (1974; cited in Shugar 1979) reports that asbestos fibers from mine tailings dumped in the region of a mussel bed, penetrated the epithelial tissue in the stomachs and intestinal tracts of mussels. No information on subsequent mussel mortality was recorded.

After considering the limited information available describing aquatic communities under the influence of high asbestos fiber concentrations, it would appear that resultant detrimental effects are minimal unless habitat degradation through eutrophication or stream destabilization accompanied the introduction of asbestos fibers. However, more information regarding the effects of asbestos fibers on aquatic organisms is required before definite conclusions can be forwarded.

5.0 CLINTON CREEK WATER QUALITY - ASBESTOS FIBRE CONTENT

5.1 Introduction

Cassiar Resources Ltd. has undertaken a water sampling program since 1978 to determine the asbestos fiber content of Clinton Creek, the Forty Mile and Yukon River. Following the blockage of upper Clinton Creek by a slumping waste dump in the spring of 1973, a water sampling program was conducted by the Department of Indian and Northern Affairs in November 1974. Their results showed relatively high concentrations of asbestos fibres; and in conjunction with the Yukon Water Board they expressed concern to Cassiar Resources Ltd. to undertake corrective measures to reduce additional asbestos input from erosion of the unstable waste piles. To meet these requests, intensive water sampling and analyses were conducted to delineate temporal and spatial additions of asbestos fibers to the Clinton Creek watershed. The results are summarized in the following section.

5.2 Methods

To determine waterborne fiber levels, a sampling program was designed to examine three areas of the Clinton Creek watershed:

1. Watercourses outside the influence of the mining activities, to provide background levels of asbestos fiber (Sample site CC-1, WC-1, EC-1, PC-1 and BC-1);
2. Clinton and Wolverine Creeks following exposure to the waste piles (Sample sites CC-2a to CC-5); and
3. The Forty Mile and Yukon River, to measure and compare asbestos fiber loading from Clinton Creek (Sample sites Y-1, 2 and FM-1, 2).

The samples sites are shown in Figure 9 and described in Appendix IV.

Sampling was conducted by dipping one litre, opaque, polyethylene bottles under the surface of the water. One millilitre of 2.7% mercuric chloride was added to the sample as a preservative. Prior to actual collection, the bottles were rinsed several times with sample water.

Water samples were shipped to Vancouver and analyzed by B.H. Levelton and Associates Ltd., utilizing Electron Microscopy and the carbon-coated nucleopore technique. This method was developed by the United States Environmental Protection Agency, the Canada Centre for Inland Waters and the Ontario Research Foundation, and is presently the accepted technique for determination of asbestos fiber concentration in water samples. A summary of the method is outlined in Appendix V. One assay of each 1 litre sample was analyzed (A.J. Shaw, B.H. Levelton and Associates Ltd; pers. comm.).

Results from B.H. Levelton and Associates Ltd. agreed with analytical results obtained with similar samples analyzed in interlaboratory evaluation programs (Schreier and Taylor 1980).

5.3 Results and Discussion

5.3.1 Asbestos Fiber Concentration

Although the sampling program was not comprehensive from 1978-1980, trends were evident in the results (Table 10).

Background levels of waterborne asbestos fibers ranged from below detection limit to a maximum of 140.7 x 10^6 fibers/litre (PC-1, 1978). Creeks upstream of mining activities on Clinton Creek had lower fiber

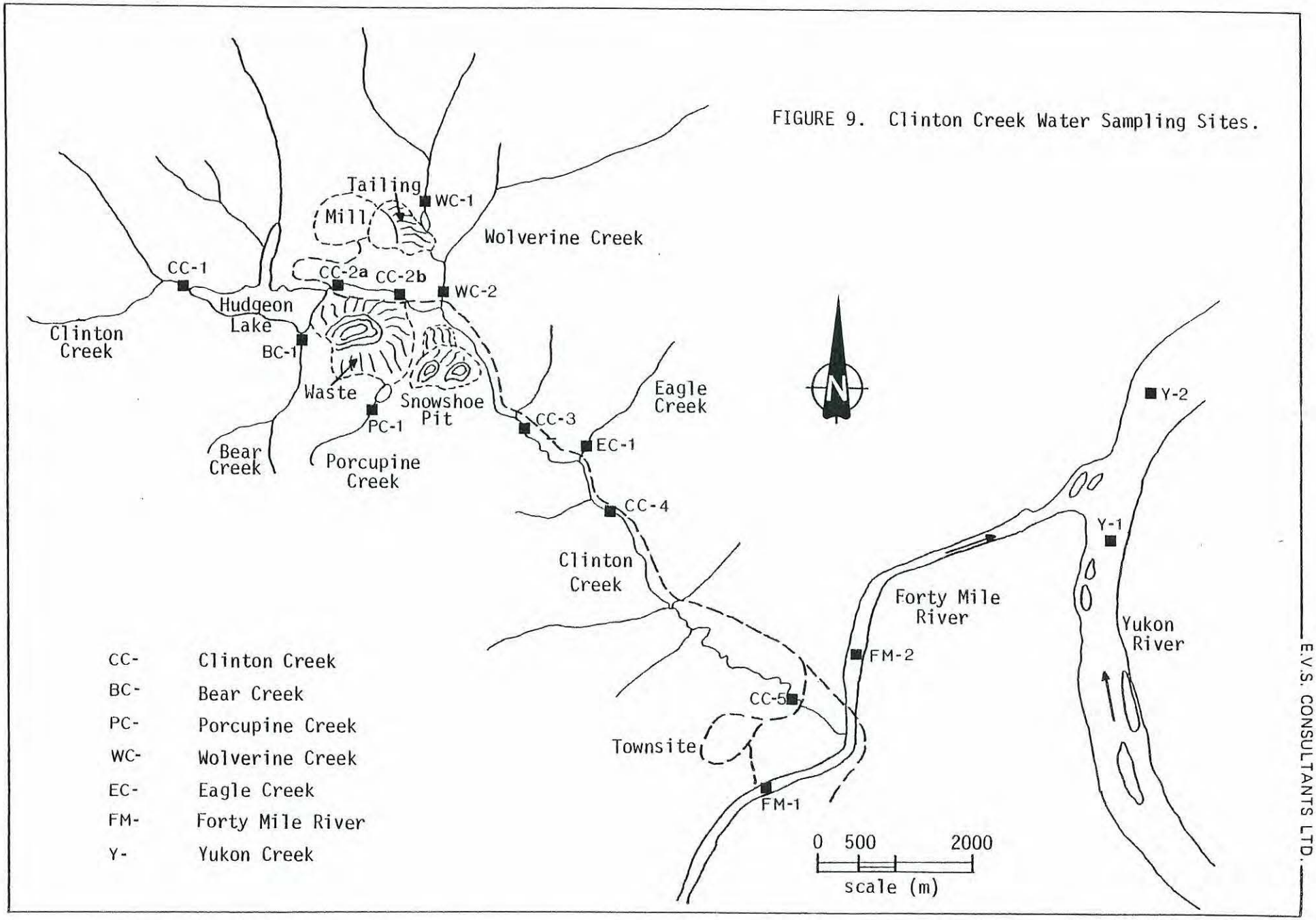


FIGURE 9. Clinton Creek Water Sampling Sites.

TABLE 10

CONCENTRATION OF ASBESTOS FIBERS (10^6 FIBERS/L) IN WATER SAMPLES FROM THE CLINTON CREEK AREA.

Location Code		Sample Date												
		1978						1979				1980		
E.V.S.	Old	May	Jun 7-27	July	Aug 3-24	Sep 7-27	Oct 5-19	May 12	Jun 25	Aug 27	Oct 5	Jul 2	Sep 6-7	Nov 14
CC-1	S-3	5.5	N.D.	N.D.	1.6	3.3	5.5		6.6	14.2	N.D.	N.D.	2.7	
CC-2a													2.7	N.D.
CC-2b	S-4	7,917	1,205	64,451	1,700.4	1,090.5	395.8	9,760	1,292	1,505	398	267.2	4.9	12.5
CC-3													154.3	
CC-4													67.6	
CC-5	S-6								36,024	3,108	3,094	665.2	166.9	41.4
FM-1	S-11								N.D.			43.6	14.7	N.D.
FM-2													2.7	
Y-1												327.2	14.7	7.1
Y-2													6.0	0.5
WC-1	S-13								38.5	5.5	20.7	16.4	N.D.	3.3
WC-2	S-12	173,399	730,676	58,344	18,299	53,546	1,040.3	45,580	401	1,908.5	54.5	395.3	188.2	208.3
EC-1												10.9	0.5	
PC-1	S-9	27.5	16.4	N.D.	30.2	140.7	11.0	137	55	N.D.	3.3		4.4	
BC-1													3.3	

N.D. = below detection limit

content compared to creek sections below the mining pit and waste piles. During 1980 the most intensive and systematic sampling was undertaken, and in general, background levels were lower compared to previous years.

Asbestos fiber loading was evident in Clinton and Wolverine Creeks donwstream of the mining activities. For example the fiber levels recorded in Wolverine Creek (WC-1 versus WC-2) showed a tremendous increase once the creek passed the dump toe. The Clinton Creek mainstem also experiences fiber loading as it flows through the mine waste piles and the confluence of Wolverine Creek.

Relatively high concentrations of fibers in the Clinton Creek mainstem samples raised the possibility of asbestos fiber transport and contamination of the Forty Mile River. However, the September 1980 sampling did not show an increase of fibers below the confluence. At this time CC-5 carried 167 x 10^6 fibers/litre compared to 2.7 and 14.7 x 10^6 fibers/litre recorded at FM-1 and FM-2 respectively (Table 10). Clinton Creek contributes very little to the total flow of the Forty Mile River; therefore input of asbestos fibers by Clinton Creek may be masked by a large dilution factor (in excess of 20 to 1).

A sample taken one kilometer above the Clinton Creek discharge (FM-1) showed 14.7 x 10^6 fibers/litre; approximately 5 times more fibers than measured at FM-2. This also occurred on the Yukon River where fiber concentrations decreased downstream of the Forty Mile River - Yukon River confluence. Samples of Yukon River water have shown natural concentrations of fibers ranging from approximately 1.5 x 10^6 to 330 x 10^6 (Tables 10 and 11).

TABLE 11

STREAM WATER SAMPLES ANALYZED FOR ASBESTOS IN BRITISH COLUMBIA AND THE YUKON TERRITORY (SHREIER AND TAYLOR 1980)

SAMPLE LOCATION	DATA	FIBER CONCENTRATION (10^6 fibers/L)	MEAN FIBER SIZE (μm)	ORGANIZATION INVOLVED IN COLLECTION OF SAMPLES
Vedder River at rwy bridge				
Right bank*	June 10, 1977	256	2.6	W.Q.B.
Right bank	June 10, 1977	228	2.4	W.Q.B.
Left bank*	June 10, 1977	141	3.4	W.Q.B.
Left bank	June 10, 1977	108	3.1	W.Q.B.
Sumas River at border				
Left bank	September 3, 1976	15,000		W.Q.B.
Centre	September 3, 1976	8,000	0.7	W.Q.B.
Right bank	September 3, 1976	13,000		W.Q.B.
Sumas River at border	January 26, 1977	100,000	-	W.Q.B.
Sumas River at border	June 10, 1977	24,000	-	W.Q.B.
Sumas River at border	August 20, 1976	620	-	P.C.B.
Sumas River above Swift Creek	September 20, 1977	490	1.26	W.Q.B.
Sumas River below Swift Creek	September 20, 1977	31,000	(0.5-2.0)	W.Q.B.
Fraser River at Mission City				
Left bank	June 10, 1977	940	-	W.Q.B.
Centre	June 10, 1977	1,000	-	W.Q.B.
Right bank	June 10, 1977	1,200	-	W.Q.B.
Upper Fraser River	November 25, 1977	8.5	4.0	P.C.B.
Fraser River at Quesnel Bridge	November 25, 1977	330	2.3	P.C.B.
Fraser River at Boston Bar	January 17, 1978	9.9	2.5	P.C.B.
Fraser River at Mission City	January 17, 1978	230	3.1	P.C.B.
Yukon River at Forty Mile	August 1977	33	2.2	W.Q.B.
Yukon River at U.S. boundary	August 1977	200	1.8	W.Q.B.
Forty Mile at Clinton Creek	November 1974	3.0	1.5	D.I.A.N.D.†

*Right and left banks facing downstream
W.Q.B. = Water Quality Branch
P.C.B. = Pollution Control Branch (B.C.)
D.I.A.N.D. = Department of Indian and Northern Affairs
†Data from Environmental Protection Service, 1977

Over the three years of data collection, there appears to be a general trend toward gradual lowering of asbestos fiber concentrations. This trend is evident by following the data for sites CC-2b, CC-5 and WC-2 (Figures 10a to 10c). For example, fiber concentrations at WC-2 have decreased from a high in June 1978 of 730,676 x 10^6 to 395 x 10^6 fibers/litre during July 1980. Stabilization of waste and tailings dumps, actions taken to impede erosion, and possibly lower annual water flows, may have contributed to the trend.

It was also evident that higher concentrations of fibers were recorded during periods of high water flow. Samples taken during May to July, when spring freshets are at their maximum, were consistently higher in fiber content than samples from fall months (Figures 10a to 10d). Higher water flow should be able to erode and carry more fibers and material than lower flow. However, Schreier and Taylor (1980) could find no conclusive evidence to support the assumption that seasonal hydrologic conditions influenced asbestos fiber transport.

The high levels of fiber concentration recorded during the spring of 1978 and 1979 were partially related to construction activities on Clinton and Wolverine Creeks. In 1978, culverts at the Minesite Bridge were reinstalled and waste material was removed from the main channel of Clinton Creek. On Wolverine Creek, an extensive project of tailings removal and weir installation was ongoing throughout the summer. In 1979, weir construction on Clinton Creek, combined with severe spring flooding, resulted in increased waterborne fiber levels.

Durham and Pang (1976) reported asbestiform fiber concentrations in open waters of Lake Superior ranging from 0.1 x 10^6 to 87.3 x 10^6 fibers/litre. Chrysotile was the most commonly occuring mineral fiber.

FIGURE 10a. Asbestos fiber concentrations at the Minesite Bridge, 1978 to 1980.

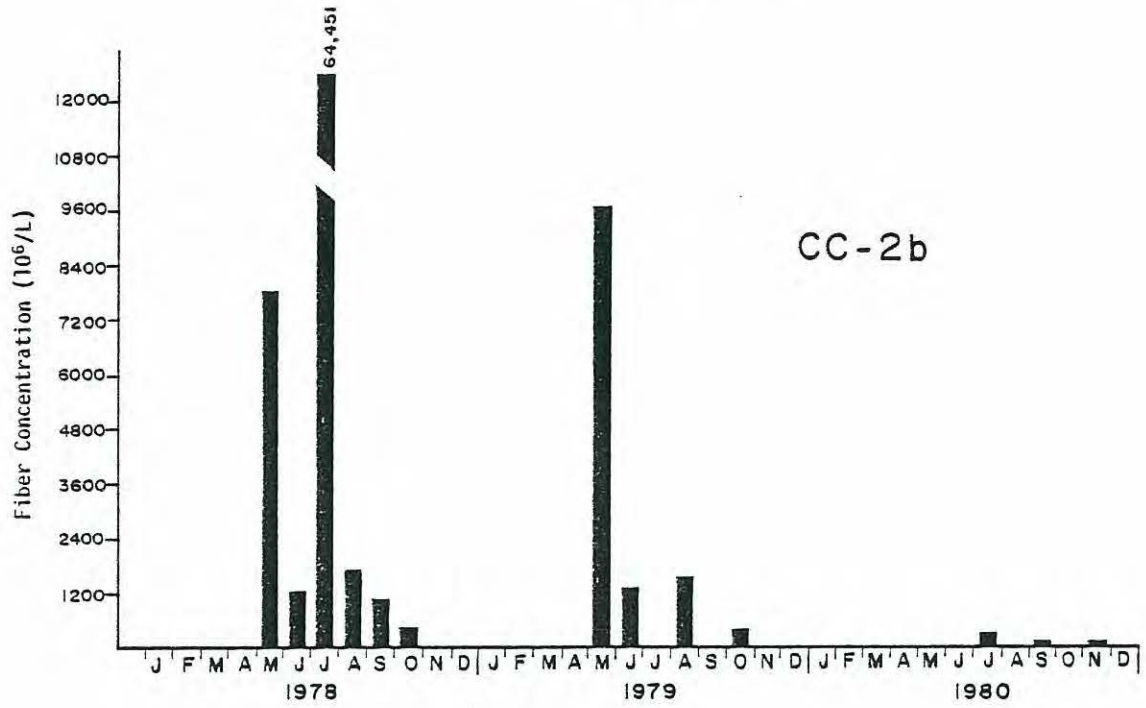


FIGURE 10b. Asbestos fiber concentrations at Alou (Townsite) Bridge, 1978 to 1980.

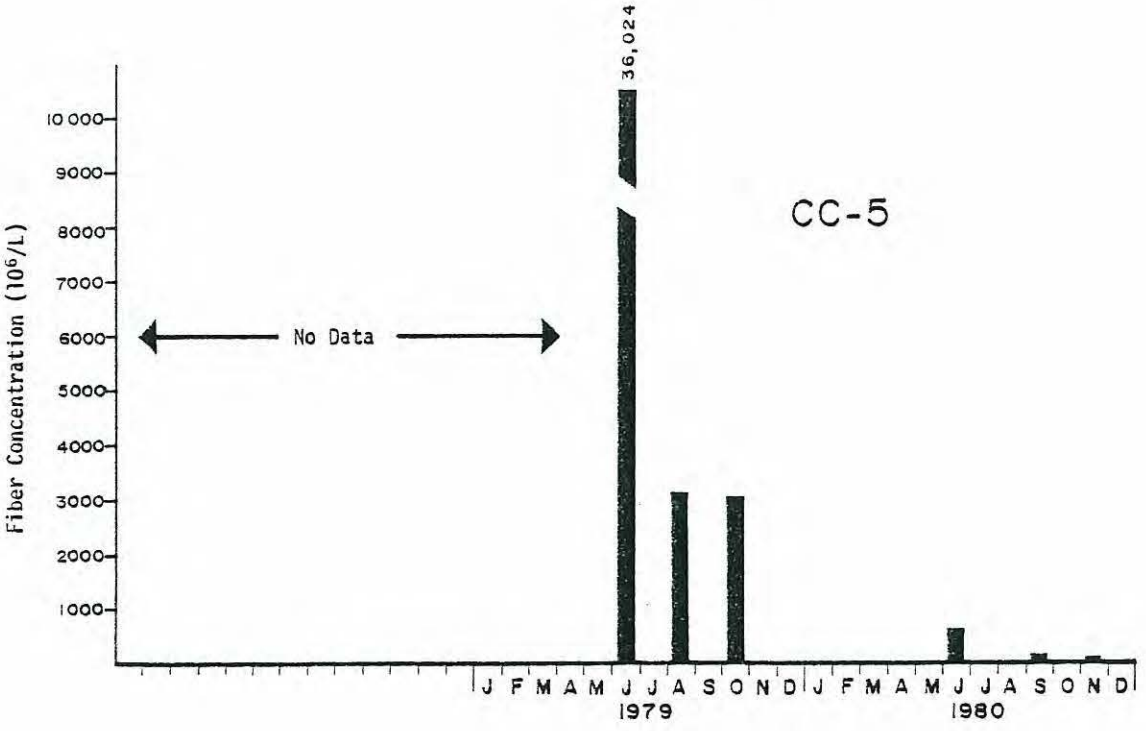


FIGURE 10c. Asbestos fiber concentrations, lower Wolverine Creek, 1978 to 1980.

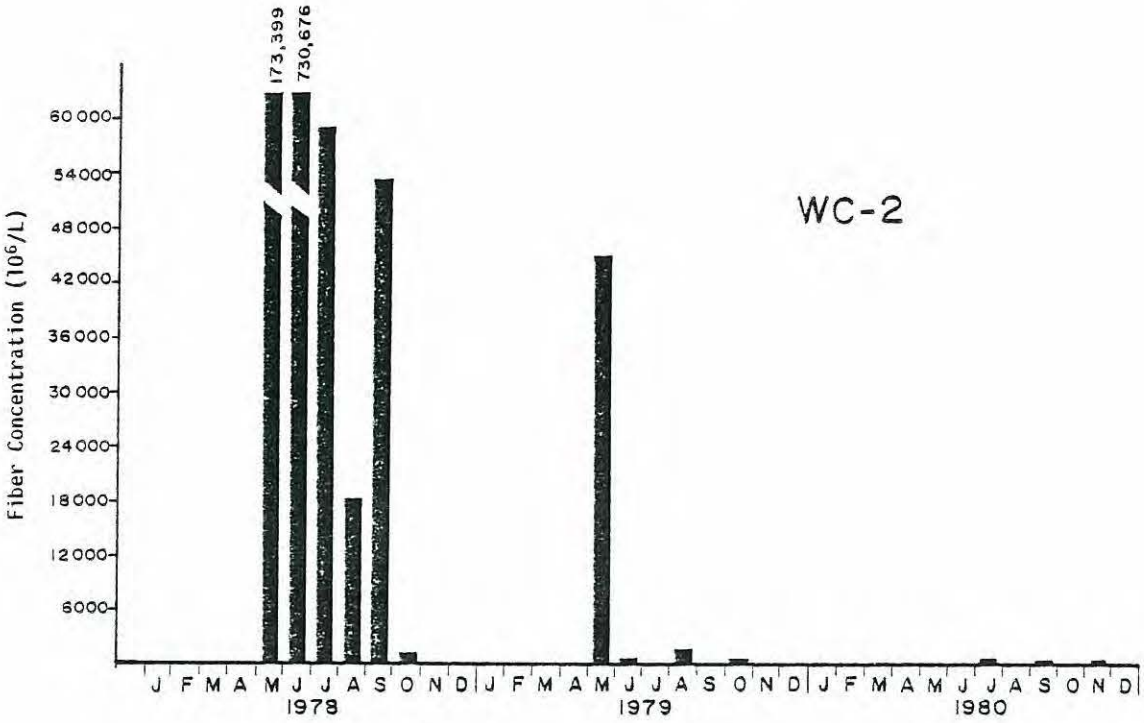


Figure 10d. Seasonal water discharge at two representative sites in the Yukon Territory.

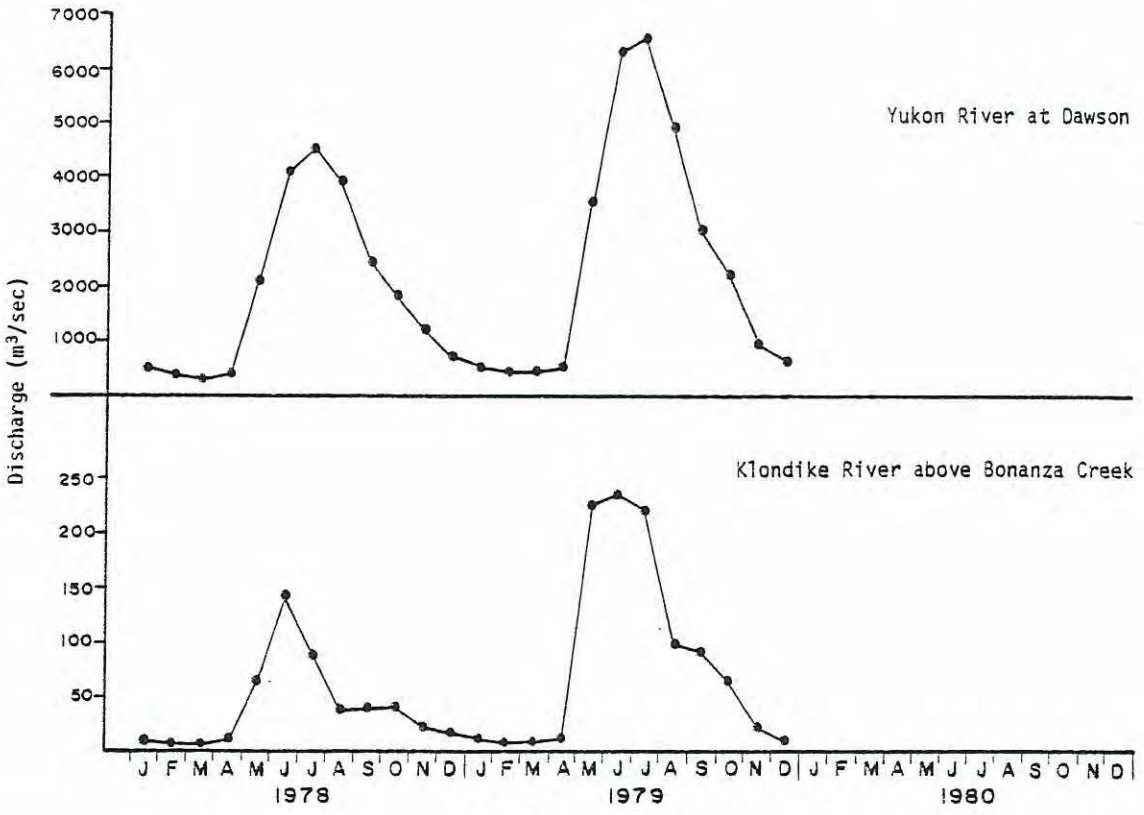


TABLE 12

ASBESTOS IN CANADIAN DRINKING WATER (FROM KAY, 1974)

SAMPLE	SOURCE	MILLIONS OF FIBERS PER LITRE
Belleville	Bay of Quinte	0.533
Brantford	Grand River	0.570
Brockville[a]	St. Lawrence River	0.446
Chatham	Thames River	0.595
Cornwall	St. Lawrence River	2.11
Hamilton	Lake Ontario	0.694
London	Lake Huron	0.456
Niagara Falls	Niagara River	2.58
North Bay[a]	Trout Lake	0.384
Oshawa	Lake Ontario	0.557
Ottawa	Ottawa River	0.136
Pembroke[a]	Ottawa River	2.85
Peterborough	Otonabee River	1.86
Port Colborne	Welland Ship Canal	0.608
Sarnia[a]	Lake Huron	3.87
Sault Ste. Marie[a]	St. Marys River	0.248
St. Catharines	Welland Ship Canal	1.03
St. Thomas	Lake Erie	1.60
Sudbury[a]	Ramsay Lake	0.297
Thunder Bay[a]	Lake Superior	0.830
Toronto	Lake Ontario	1.90
Welland	Welland Ship Canal	0.820

[a]No filtration plant

TABLE 13

ASBESTOS IN CANADIAN RIVERS AND LAKES, AND IN DRINKING WATER[a]
(FROM CUNNINGHAM AND PONTEFRACT 1971)

LOCATION	SOURCE	TYPE OF WATER	CONCENTRATION (MILLIONS OF FIBERS PER LITRE)
Ottawa	Ottawa River	tap water	2.0
Toronto	Lake Ontario	tap water	4.4
Montreal	St. Lawrence River	tap water	2.4
Hull	Ottawa River	tap water	9.5*
Beauport	St. Lawrence River	tap water	8.1*
Drummondville	St. Français	tap water	2.9
Asbestos	Nicolet River	tap water	5.9
Thetford Mines	Lac à la truite	tap water	172.7*
Ottawa	top 30 cm	melted snow	33.5
Ottawa	Ottawa River	river water	9.5

[a]Identification and measurement by electron diffraction and T.E.M.
(*Water supply not filtered).

TABLE 14

ASBESTOS FIBERS IN BEVERAGES (CUNNINGHAM AND PONTEFRACT 1971)

BEVERAGE	SOURCE	MILLIONS OF FIBERS PER LITRE
Beer	Canadian	4.3
Beer	Canadian	6.6
Beer	U.S.A.	2.0
Beer	U.S.A.	1.1
Sherry	Canadian	4.1
Sherry	Spanish	2.0
Sherry	South Africa	2.6
Port	Canadian	2.1
Vermouth	French	1.8
Vermouth	Italian	11.7
Ginger ale		12.2
Tonic water		1.7
Tonic water		1.7
Orange (soft drink)		2.5

Kay (1974) found fiber concentrations up to 3.87 x 10^6 fibers/litre in Ontario drinking water (Table 12), while analysis by Cunningham and Pontefract (1971) revealed fiber concentrations of 2.0 x 10^6 to 173 x 10^6 fibers/litre in drinking water samples (Table 13). Fiber concentrations up to 12.2 x 10^6 have been reported from popular beverages (Table 14).

Background asbestos fiber concentrations in Canada are generally considered to be about 1.0 x 10^6 fibers/litre (Kramer and Murdoch 1974, cited in National Health and Welfare Canada 1980). Reported background levels have ranged from less than 1.0 x 10^6 to 10 x 10^6 fibers/litre (National Health and Welfare Canada 1980, Lawrence and Zimmerman 1977). Levels of waterborne asbestos fibers originating from natural sources in the United States may be as high as 100 x 10^6 fibers/litre (U.S. EPA 1976). Oliver and Murr (1977) found 2200 x 10^6 fibers/litre in ground water samples from the Rio Grande Valley.

Table 15 summarizes data describing asbestos fiber content of raw drinking water supplies across Canada. Fiber concentrations ranged from below detection limits to 270 x 10^6 fibers/litre. (Values stated as "zero" are erroneous and should have been reported as below detection limits by Chatfield and Dillon). Samples from regions of major asbestos deposits generally exhibit higher fiber concentrations ranging from 25 x 10^6 to 400 x 10^6 fibers/liter. Samples taken during 1980 from the Clinton Creek mainstem revealed similar fiber concentrations of 2.7 x 10^6 to 167 x 10^6 fibers/litre. The extreme fiber concentrations found in Wolverine Creek (730,676 x 10^6 fibers/litre, June 1978) were comparable to natural concentrations found in water samples from the Sumas River in southwestern British Columbia (Table 11). Natural erosion of asbestos bearing geological formations is believed to be the cause of such high concentrations in the Sumas (J. Taylor, pers. comm.). Also, fiber concentrations of 200-300 x 10^6 fibers/litre found in Wolverine Creek during 1980 were of the same magnitude as those observed in drinking water supplies of asbestos mining towns in Quebec (Table 12).

TABLE 15

ASBESTOS FIBER CONCENTRATIONS (10^6 FIBERS/L) OF RAW DRINKING WATER SUPPLIES FROM SITES ACROSS CANADA (CHATFIELD AND DILLON, 1979)

PROVINCE	CITY	FIBER CONC.
Yukon Territory	Dawson City	13
	Whitehorse	270
Northwest Territories	Inuvik	0-0.5
	Yellowknife	3
British Columbia	Kamloops	11
	Prince Rupert	1.5
	Vancouver	0-0.5
	Victoria	0-0.5
Alberta	Calgary	1
	Edmonton	0-3
	Lethbridge	83
	Medicine Hat	6.5
Saskatchewan	Prince Albert	8.5
	Regina	2.5
	Saskatoon	4
	Swift Current	0-1.5
Manitoba	Flin Flon	0-0.5
	Portage La Prairie	36
	Selkirk	31
	Thompson	190
	Winnipeg	0-0.5
Ontario	Hamilton	0-0.5
	Kingston	0-0.5
	London	1
	Matachewan	0-0.5
	Matheson	7.5
	North Bay	0-0.5
	Ottawa	4.5
	Peterborough	0-0.5
	Sudbury	0-0.5
	Thunder Bay	2
Ontario (cont.)	Toronto	0-0.5
	Windsor	1.5
Quebec	Chicoutimi	0-1
	East Broughton	1
	Hull	0.5
	Montreal	2
	Quebec	3
	Sherbrooke	73
	Trois Rivières	0-0.5
New Brunswick	Fredericton	0-1
	Moncton	0-0.5
	St. John	0-0.5
Nova Scotia	Halifax	1.5
	Sydney	0-0.5
Newfoundland	Corner Brook	0-0.5
	Gander	2
	La Scie	7
	St. George's	0.5
	St. John's	0-1
Prince Edward Island	Charlottetown	0-0.5
	Summerside	0-1
ASBESTOS DEPOSIT AREAS		
British Columbia	Cassiar	25
Quebec	Asbestos	170
Quebec	Thetford Mines	140*
Quebec	Disraeli	220
Newfoundland	Baie Verte	400

*Treated water output - no filtration

Samples from any site in the Clinton Creek area had concentrations of similar magnitude to samples obtained along the lower Fraser, Sumas and Vedder Rivers (Table 11). A study completed by the United States Environmental Protection Agency (1977) revealed that in most cases mining operations did not increase fiber concentrations, contrary to findings at Clinton Creek. This may reflect the high concentration, easy erosion and suspension of fibers from waste materials at Clinton Creek.

In light of present data, it did not appear that Clinton Creek contributed significantly to the asbestos fiber load of the Forty Mile or Yukon Rivers. These streams carry relatively high fiber loads from natural erosion of metamorphic, asbestos-bearing geology. Concentrations found in these streams were similar to those of comparable river systems (Fraser River) and Canadian drinking water supplies. Localized elevations of fiber content in Clinton and Wolverine Creek water were due to the easy erosion of material with high asbestos fiber content. A systematic sampling program using sites delineated by E.V.S. Consultants Ltd. (Figure 9) may be required to strengthen conclusions regarding fiber transport in Clinton Creek to the Forty Mile and Yukon systems.

5.3.2 Asbestos Fiber Lengths

Results of water samples analyses for fiber lengths are summarized in Table 16.

Fibers encountered in Clinton Creek water ranged in length from 0.5 to 130 micrometers in length. The mean fiber length for all data collected from 1978 to 1980 was 4.912 micrometers (standard error of mean (SEM) $\pm$0.605).

TABLE 16

AVERAGE AND RANGE ( ) OF ASBESTOS FIBER LENGTHS (MICROMETERS) FORM WATER SAMPLES TAKEN FROM CLINTON CREEK AREA.

Location Code		Sample Date												
		1978						1979				1980		
E.V.S.	Old	May	Jun 7-27	July	Aug 3-24	Sep 7-27	Oct 5-19	May 12	Jun 25	Aug 27	Oct 5	Jul 2	Sep 6-7	Nov 14
CC-1	S-3	8.5 (3-14)			3.7 (3-5)	5.7 (2-10)	4.9 (1-9)		0.8 (0.5-1.5)	1.1 (0.5-3)			2.5 (1-4)	
CC-2a													6.4 (1-18)	
CC-2b	S-4	5.0 (.5-35)	5.2 (.5-110)	2.8 (.5-25)	5.6 (1-60)	5.2 (.5-95)	4.5 (1-26)	7.3 (1-65)	6.1 (.5-72)	6.9 (.5-90)	8.0 (.5-100)	4.0	2.6 (1-4)	2.4 (0.5-9)
CC-3													3.3 (0.5-65)	
CC-4													4.1 (0.5-48)	
CC-5	S-6								4.0 (0.5-54)	3.1 (0.5-16)	2.8 (0.5-22)	2.8	4.5 (0.5-45)	5.9 (1-40)
FM-1	S-11											3.0	2.2 (0.5-9)	
FM-2													10.8 (2-40)	
Y-1												3.0	2.4 (1-12)	2.0 (1-6)
Y-2													2.3 (1-6)	1.0
WC-1	S-13								2.3 (1-5)	2.9 (1-5)	6.2 (1-32)			4.0 (3-5)
WC-2	S-12	7.4 (1-130)	5.8 (0.5-105)	5.2 (0.5-46)	3.9 (1-22)	5.8 (0.5-35)	5.8 (1-80)	5.0 (1-100)	3.5 (0.5-82)	3.3 (1-14)	3.4 (1-8)	2.0	3.0 (0.5-46)	2.0 (1-20)
EC-1												2.2	0.5	
PC-1	S-9	3.4 (1-6)	38.6 (18-50)		4.5 (1-12)	5.4 (0.5-54)	5.4 (1-10)	3.0 (1-16)	3.3 (1-5)		13 (2-30)		3.0 (1-5)	
BC-1													14 (12-16)	

TABLE 17

MEAN ASBESTOS FIBER LENGTHS (MICROMETERS) OBSERVED FROM CLINTON CREEK WATER SAMPLES, 1978 TO 1980.

	n	$\bar{x}$ FIBER LENGTH ±S.E.M.[a]
overall	66	4.91 ± 0.605
1978	21	6.78 1.614
1979	19	4.53 0.659
1980	26	3.69 0.570
CC-1	7	3.89 1.033
CC-2b	13	5.05 0.494
CC-5	6	3.85 0.497
WC-1	4	3.85 0.859
WC-2	13	4.32 0.457
PC-1	9	8.84 3.862 [b]
BC-1	1	14.0 (12-16)

[a] Standard Error of Mean
[b] Individual sample, mean length and range

TABLE 18

APPROXIMATE MEDIAN ASBESTOS FIBER LENGTHS (MICROMETERS) OBSERVED IN SAMPLES FROM WATER DISTRIBUTION SYSTEMS (CHATFIELD AND DILLON, 1979).

CITY	MEDIAN	RANGE
Cassiar, B.C.	0.70	≈0.30-22.0
Kamloops, B.C.	0.70	0.30- 7.0
Vancouver, B.C.	0.50	0.30- 5.0
Baie Verte, Nfld.	0.60	0.30-10.5
Gander, Nfld.	0.50	0.30- 1.5
La Scie, Nfld.	0.50	0.30- 3.5
Beaulac, Que.	0.60	0.30- 4.5
Disraeli, Que.	0.50	0.30- 3.5
Sherbrooke, Que.	0.55	0.30- 5.0
Thetford Mines Que.	0.55	0.30-10.0
Whitehorse, YT.	0.55	0.30- 4.5

N.B. Water samples from distribution systems lacking filtration. Fiber concentrations are greater than 5×10^6 fibers/litre in all cases.

A trend of decreasing mean fiber length was noted from Table 17. The 1978 samples exhibited a mean of 6.78 micrometers (SEM $\pm$1.614) while 1980 samples were shorter, 3.69 micrometers (SEM $\pm$0.510).

There was no relation between fiber length and concentration. Further, the date of sampling had no obvious relation to fiber length; that is, a sample taken during spring freshet did not necessarily have longer fibers than a sample collected during low flow.

Fibers being carried into the mined area were approximately 3.85 to 3.90 micrometers. Immediately after contact with mined areas, lengths increased to 5.0 micrometers. Before entering the Forty Mile River the mean fiber length decreased, to average lengths recorded before mine contact.

Mean fiber length increased within the Forty Mile River downstream of the confluence with Clinton Creek (FM-1: 2.2 micrometers to FM-2: 10.8 micrometers). This may have been caused by re-erosion of fibers from the bar at the mouth of Clinton Creek. However, data for the sample sites affected by this process (FM-1 & 2) were limited to 1 sample period.

Fiber lengths in the Yukon River ranged from 1 to 12 micrometers (mean = 2.4 micrometers). No change in size was noted downstream of the Forty Mile River confluence.

Fibers from Porcupine and Bear Creeks were significantly longer than fibers from other sites (Table 17). These creeks flowed from untouched areas behind the mining activities, and they contain low grade asbestos deposits (D. Acason; pers. comm.). Slow erosion may have resulted in longer fibers.

Studies by Chatfield and Dillon (1979) on Canadian drinking water supplies revealed median fiber lengths between 0.5 and 0.8 micrometers (Table 18). Some fibers ranging up to 50 micrometers were observed but not in large numbers or a majority of samples. Long fibers were usually associated with samples near asbestos mining areas (e.g. Cassiar, B.C.; Thetford Mines, Quebec).

In the United States, waterborne asbestos fibers from natural sources were usually less than 5 micrometers in length. Fibers greater than 5 micrometers were found in significant amounts in water samples originating from asbestos product manufacture sources (U.S. EPA 1976). Fiber lengths at Clinton Creek averaged longer than those found at other locations across Canada. This may have been related to the close proximity of easily eroded material containing large amounts of asbestos fibers.

The literature does not contain conclusive information regarding the biological significance of fiber length. Smaller fibers are known to cross body barriers more readily, and can thus reach sites of potential human carcinogenesis (U.S. EPA 1980). Although quantitative data are limited, longer fibers may also be carcinogenic. The relative importance of fiber length has not been accurately determined.

6.0 CRITICAL ASSESSMENT OF EFFECTS OF INGESTION OF ASBESTOS FIBERS

The hazards of orally ingested asbestos fibers are not thoroughly understood, and the extent of data concerning the uptake of asbestos fibers and subsequent effects on human physiology is limited. Some studies on the effects of asbestos ingestion in experimental animals have been undertaken, and attempts have been made to correlate asbestos fiber concentrations in potable water with increases in gastro-intestinal cancer.

Comparatively little attention has been directed to the fate and effects of asbestos fibers in the gastrointestinal tract. The identification of asbestos fibers in relatively high concentrations in beverages as well as potable water (Tables 13 and 14) has raised the level of concern regarding ingested asbestos fibers and the possibility of subsequent carcinogenic effects on viscera and internal organs. Potentially, asbestos can be ingested directly as a trace contaminant in liquids and food, or drug administration. Schneiderman (1974) concluded from a review of the literature that inhaled asbestos fibers can reach the gastrointestinal tract via ingested sputum, resulting in increased digestive system cancer.

Evidence exists that chrysotile and amphibole fibers penetrate the intestinal mucosa of experimental animals (Westlake et al. 1965; Pontefract and Cunningham 1973; Brown 1974; Lee 1974; Pontefract 1974a, 1974b; Pooley 1974; Webster 1974; Cunningham et al. 1977; and Storeygard and Brown 1977). Cook and Olson (1979) published data concerning asbestos fibers in human urine which provided definite evidence of asbestos fiber penetration of the gastrointestinal tract.

Their findings contradicted earlier conclusions (Smith 1973; Davis et al. 1974; Gross et al. 1974; Zaidi et al. 1976; and Bolton and Davis 1976) that there was no evidence of penetration of asbestos fibers into the walls of the gastrointestinal tract.

A number of studies have examined the effects of asbestos fibers in the digestive tracts of experimental animals. Gibel et al. (1976) observed malignant tumour formation in rats fed asbestos fiber material, while Jacobs et al. (1978) reported that large amounts of chrysotile resulted in changes in the mucosal lining cells of the ileum, consistent with mineral induced cytotoxicity. However, the majority of researchers (Smith 1973; Gross et al. 1974; Lee 1974; Webster 1974; Westlake 1974; and Cunningham et al. 1977) concluded that asbestos fibers did not cause extensive damage or cancer of the gastrointestinal tract in experimental animals. A major study designed to obtain definitive results regarding the ingestion of asbestos fibers by hamsters and rats is currently being conducted by the United States Environmental Protection Agency. Results will not be released until late 1981 (R. Shapiro, pers. comm.).

Chrysotile asbestos may interfere with DNA synthesis. Short term experimentation involving ingestion of single doses of chrysotile fibers, in saline suspension, resulted in increased synthesis of DNA in the stomach, duodenum and jejunum, while synthesis decreased in the liver (Amacher et al. 1974, 1975; Epstein and Varnes 1976). It was concluded that fibers enhanced mitosis by interaction with nuclear DNA, or accelerated cell death with subsequent bursts in replacement cell mitotic activity. The latter suggestion was supported by Jacobs et al. (1977, cited in Jacobs et al. 1978). The significance of this phenomenon in terms of effects on the gastrointestinal tract is unknown.

Asbestos fibers can be transported by the blood stream or lymphatic system to sites not normally exposed as points of entry, leading to the concern that other organs, more susceptable than the lungs or intestine may be exposed to asbestos by lymphatic or bloodstream transfer (Westlake et al. 1965; Roe et al. 1967, cited in Davis et al. 1974; Kanazawa et al. 1970; Cunningham and Pontefract 1973; Brown 1974; Pontefract 1974; Pontefract and Cunningham 1974; Westlake 1974; and Sebastien 1979). Cunningham and Pontefract (1974) observed the placental transfer of asbestos fibers to developing fetuses, and Graham and Graham (1967) claimed that asbestos fibers could be associated with ovarian cancer. None-the-less Schnieder and Maurer (1977) could find no evidence that administration of chrysotile asbestos affected embryo implantation or survival in pregnant mice.

Epidemiological studies have attempted to determine if exposure to high asbestos fiber concentrations in drinking water was detrimental to inhabitants of affected communities. Situations have developed in Duluth, Minnesota where taconite tailings (said to contain a form of asbestos) have contaminated water supplies, and in the Eastern Townships of Quebec where ambient asbestos levels have been historically high due to the proximity of natural asbestos deposits under exploitation. Auerbach et al. (1977) hypothesized that if large numbers of asbestos fibers were taken into the blood stream as a result of exposure to contaminated drinking water, some may lodge in the lungs to produce asbestos bodies. To evaluate this hypothesis, lungs of recently deceased Duluth, Minnesota residents (which had a contaminated water supply) were analysed. No increase in asbestos bodies in lung tissue was observed between people that had been exposed to contaminated water and those who were not. Carter and Taylor (1980) found chrysotile fibers in relatively high concentrations in living residents of Duluth and control subjects. Liver and jejunum samples from Duluth subjects did not differ significantly from background levels inferred from experimental laboratory contamination tests with other organisms.

Asbestos fibers in drinking water have not yet been associated with excess cancer rates. Epidemiological studies in Duluth, Minneapolis and St. Paul (Minnesota) (Masson et al. 1974; Levy et al. 1976), and in the Puget Sound area (Severson 1979, cited in Meigs et al. 1980) concluded that asbestos in water had not contributed to increased cancers. Morgan (1975) stated that no increase in death rates due to gastro-intestinal cancer has been shown in Duluth. In fact, the death rate for cancer of the gastrointestinal tract was lower in Duluth than in other parts of Minnesota. Morgan cited the conclusion of the International Agency for Cancer Research (Lyon 1972) that there was no evidence that exposure of the general population to small amounts of asbestos fibers in beverages, drinking water or food increased the risk of cancer.

Cooper et al. (1979, cited in Millette et al. 1980) obtained data on residents of the San Francisco area, (where asbestos concentrations ranged up to 36 million fibers per litre), that suggested a weak correlation between asbestos levels in water and cancers of the digestive tract. However, the senior author, in an undated manuscript, stated that the results did not necessarily show a cause and effect relationship between asbestos levels and cancer, but were suggestive of further research needs.

Wigle (1977) evaluated the mortality of twenty-two municipalities in Quebec grouped by evidence of exposure to asbestos fibers in water supplies. The study did not reveal evidence of excess cancer mortality attributable to exposure of asbestos in drinking water. Excess mortality due to cancers of the stomach and lungs in males, and the pancreas in females, were observed in two municipalities with known high exposures. Excesses among males suggested a link to occupational exposure. The absence of pancreatic cancer among males suggested that the mortality observed among females was not due to waterborne asbestos.

Increased concern over the possibility of gastrointestinal cancer risk from utilization of asbestos-cement pipe prompted Harrington et al. (1978) to compare arbitrary asbestos risk scores with age adjusted, sex specific incidence data, covering a period of 38 years, for stomach, colon and rectal cancer in Connecticut townships. No association was observed between asbestos risk and gastrointestnal tumour incidence. In a similar investigation, Meigs et al. (1980) tested eight measurements related to asbestos in town water, population density and socio-economics scores for association with increased rates of cancer incidence. No consistent patterns of association were found. The opinions of McCullagh (1980) support these findings. After reviewing available literature, he concluded that asbestos does not appear to act as a potent gut carcinogen in humans or other animals. If effects were observed, it was usually due to occupational exposure and swallowing of substantial amounts of asbestos after inhalation (as in Schneiderman 1974), not to the small amounts of asbestos naturally occurring in potable water.

Fears (1976) was also concerned with the increase in risk of cancer associated with naturally occurring asbestos. A subsequent study of cancer mortality rates in countries with and without asbestos deposits provided no evidence that high, naturally occurring asbestos levels represented an increased risk for exposed inhabitants.

Merliss (1971) suggested that asbestos contaminated talc, used to polish rice, could account for the high incidence of stomach cancer in Japan. Henderson et al. (1975) investigated representative tumours of Japanese males and found the presence of several mineral materials, including amphibole and chrysotile. However, Smith (1973) observed that nitrates occur at high levels in grains, while constituent amines are at high concentrations in Japanese dried fish. He therefore proposed that carcinogenic nitrosamines, produced by interaction of nitrates with secondary or tertiary amines in the stomach, caused the cancers.

While summarizing the relationship of asbestos fibers and the gastrointestinal tract, Selikoff and Lee (1978, Chapter 14) concluded that it was possible for asbestos fibers to enter the wall of the cecum, lower colon and rectum, under suitable conditions, where they may participate in carcinogenesis. Therefore, persons occupationally exposed to asbestos dust will have a significantly increased gastrointestinal burden and may be liable to tumour formation. People receiving more than background dosage from drinking water, or beverages contaminated with asbestos, may have an increased gastrointestinal input, but the risk of tumour development cannot be defined at present. In spite of several major epidemiological studies, no evidence exists associating intake of asbestos with cancer of the cecum, colon or rectum in the general population. It is probable, however, that the risk of these cancers is increased in those occupationally exposed to inhalation.

Personal communications with Dr. P. Cook (Research Chemist, Environmental Research Laboratory, Duluth, Minnesota) indicated that present U.S. EPA water quality criteria may overestimate the risk of gastrointestinal cancer from ingested asbestos, because the existing criteria are based on occupational exposure and risks of gastrointestinal cancer were calculated relative to amounts of asbestos ingested after inhalation. The risk of gastrointestinal cancer is presently estimated as one excess cancer per 100,000 people over an average lifetime of 70 years, if asbestos exposure approaches 3.0×10^5 fibers per litre at a level of 2 litres per day (U.S. EPA, 1980). This estimation was based on available worst case evidence, and it must be recognized that there are significant uncertainties in the data base. However, the amount of asbestos ingested via this mechanism (inhalation and subsequent ingestion of sputum) is very large in comparison to amounts ingested from drinking water (Gross 1974; Spiel 1974, cited in McCullagh, 1980). If

the risk and formation of gastrointestinal tumours is dose-related, as suggested by Schneiderman (1974), the risk of gastrointestinal cancer from exposure to asbestos fiber contaminated drinking water would be very small, especially when risks associated with chronic ingestion after occupational exposure are small.

Dr. G.C. Becking (Chief; Environmental Toxicology Division, Health and Welfare Canada, pers, comm.) stated that there was insufficient information at this time upon which to set maximum limits for asbestos fiber concentrations in drinking water. He noted that the results of the NIEHS studies in North Carolina may imply the need for a review of existing Canadian drinking water quality standards for asbestos.

Table 19 summarizes the reported effects and conclusions of asbestos ingestion.

TABLE 19. SUMMARY OF LITERATURE REVIEWED: REPORTED EFFECTS AND CONCLUSIONS

AUTHOR	TYPE OF STUDY	RESULTS OR CONCLUSIONS
Amacher et al. (1975)	animal experimentation	DNA synthesis studies suggested that asbestos penetrates gastrointestinal mucosa and influences regulation of DNA synthesis in the G.I. tract.
Auerbach et al. (1977)	human autopsies	No increases of asbestos bodies in lung tissue resulting from exposure to contaminated drinking water.
Brown (1974)	perspective, animal experimentation	Blood and lymphatic systems can transport fibers throughout the body. How does body rid them? What damage is caused? What accumulation levels required before disease development?
Bolton and Davis (1976)	animal experimentation	No evidence of cell penetration or damage to intestinal mucosa in rat intestine after short term exposure to asbestos laden food.
Carter and Taylor (1980)	human autopsy	Viceral tissue examined for amphibole content. Subjects exposed to high oral and tissue analysis intakes exhibited fibers in tissues. Controls had few fibers. Subjects had chrysotile fibers in tissues examined.
Cook and Olson (1979)	human urine analysis	Amphibole fibers originating from ingestion of contaminated drinking water were found in urine sediments. Direct evidence for passage of fibers through intestinal mucosa.
Cunningham et al. (1977)	animal experimentation	Rats fed food laced with asbestos fibers. Concluded that trace amounts of asbestos can penetrate walls of gastrointestinal tract but no evidence to show it can cause cancer.
Cunningham and Pontefract (1973)	animal experimentation and fiber content of beverages	Asbestos fibers found in beverages and soft drinks at levels of 1.0 to 11 x 10^6 fibers/litre. Fibers injected into rat stomachs were recovered from a variety of non-gastric tissues.
Cunningham and Pontefract (1974)	animal experimentation	Asbestos fibers were discovered in developing fetuses of mice injected with asbestos fibers.
Davis et al. (1974)	perspective, animal experimentation	Only cells which actively incorporate asbestos fibers by phagocytosis regularly contain asbestos. No evidence of dust penetration through or between gut epithelial cells.
Epstein and Varnes (1976)	animal experimentation	Single oral administration of chrysotile asbestos to monkeys resulted in the stimulation of DNA synthesis in the pancreas 9 days later as evidenced by increased incorporation of tritiated thymidine.
Fears (1976)	human epidemiology	Study of cancer mortality rates provided no evidence that naturally occurring asbestos was a hazard to the general population of areas with asbestos deposits.
Gibel et al. (1976)	animal experimentation	Significant increase in numbers of tumours in rats fed asbestos filter material suggested a causal connection between development of tumours and ingestion of asbestos. No malignant tumours were found in the gastrointestinal tract.
Graham and Graham (1967)	animal experimentation	Observations after intraperitoneal injections of asbestos into guinea pigs and rabbits were compatible with the thesis that asbestos is an etiological factor in ovarian cancer.

AUTHOR	TYPE OF STUDY	RESULTS OR CONCLUSIONS
Gross et al. (1974)	animal experimentation	Animals fed asbestos over lifetime, and living to age of cancer production, failed to provide evidence of a cancerogenic effect. No evidence of tissue penetration by ingested mineral fibers.
Hammond and Selikoff (1973)	human epidemiology	Data suggested that cigarette smoking can increase the effects of inhaled asbestos via a synergistic mechanism. Risks of death from asbestos-associated disease are increased.
Harrington et al. (1978)	human epidemiology	No association was observed between asbestos risk scores and gastrointestinal cancer, caused by exposure to drinking water contamination by asbestos cement pipes.
Hendersen et al. (1975)	human autopsy and tissue analysis	Particulate material in stomach tumours of Japanese males was studied. Amphibole and chrysotile can be found associated with stomach tumours.
Jacobs et al. (1978)	animal experimentation	Rats fed diets containing 0.5 or 50 mg of chrysotile each day for 1 week or 14 months. Asbestos induced changes in rat intestine visible at both light and electron microscope levels.
Kanazawa et al. (1970)	animal experimentation	Migration of asbestos fibers along lymphatic pathways. Fibers accumulated in lymphoid tissue, particularly in axillary nodes. Small numbers of fibers found in spleen, liver, kidneys and brain suggested blood stream dispersal.
Lee (1974)	perspective, animal experimentation	No direct proof that ingestion of asbestos fibers in water increased risk of abdominal tumours. No doubt that asbestos can move in tissues, but whether they do in significant quantities or sufficient amounts to cause cancer remains to be observed.
Levy et al. (1976)	human epidemiology	No consistent pattern of statistically significant observations in numbers of gastro-intestinal cancers. No increases in numbers of cancers in Duluth residents over four years. Long lag time between exposure and eventual diagnosis in most cancer cases.
Masson et al. (1974)	human epidemiology	Asbestos-like fibers entered water supply of Duluth (Minn.) in 1955. In next 14 years no carcinogenic effects were detected among residents of all ages. Period of observation short relative to latent period for occupationally induced carcinogenic effects from asbestos.
McCullagh (1980)	perspective, human epidemiology	Asbestos does not appear to act as a potent gut carcinogen. In humans it appears only to act in those who are occupationally exposed and who swallow substantial amounts following inhalation. Amounts of asbestos naturally occurring in potable waters are so small that one would not expect them to induce gut cancer.
McDonald et al. (1971)	human epidemiology	Studies of occupationally exposed Quebec asbestos miners revealed excesses in respiratory, cardiovascular, and malignant disease for workers exposed to high airborne dust levels.
Meigs et al (1980)	human epidemiology	Eight measurements related to asbestos in town water, population density and socio-economic scores were tested for their association with increased rates of cancer incidence. No consistent patterns of association were found.
Merliss (1971)	human autopsies, epidemiology	Excesses in stomach tumours among Japanese may be due to talc (or contaminating fibers) used to polish rice.

AUTHOR	TYPE OF STUDY	RESULTS OR CONCLUSIONS
Millette et al. (1980)	perspective, human epidemiology, drinking water analysis	Fiber concentrations in cisterns collecting water from tile roofs found to be very high. Study of residents around San Francisco showed a weak significant association between asbestos levels in water and cancers of the digestive tract (Cooper et al. 1979).
Morgan, (1975)	perspective, human epidemiology	No evidence that exposure of general population to small amounts of asbestos fibers in beverages, drinking water or food increases the risk of cancer.
Pooley (1974)	perspective, animal experimentation	Gastrointestinal tract is an open-ended continuous system. Ingested particles need not contact or penetrate wall. Unless system is overloaded, unlikely to bring about damage. Lungs are not damaged until a considerable amount of material accumulated.
Pontefract (1974a) and (1974b)	perspective, animal experimentation	Chrysotile fibers injected into rat stomachs were eventually isolated from various non-gastric tissues. Asbestos can penetrate mucosa of stomach and intestine then enter the bloodstream of experimental animals. No conclusions on health hazards of orally ingested asbestos.
Schnieder and Maurer (1977)	animal experimentation	Chrysotile asbestos administered via drinking water to pregnant mice to day 4 blastocysts in culture, did not affect embryo implantation or survival.
Smith (1973)	animal experimentation	Hamsters maintained on a 1% diet of chrysotile or amosite produced no evidence of tumours caused by asbestos fibers. Opposes Merliss (1971) by claiming excess tumours are caused by carcinogenic nitrosamines produced by Japanese diet.
Storeygard and Brown (1977)	animal experimentation	Amosite fibers suspended in saline were placed in an isolated segment of rat jejunum in vivo. Fibers penetrated the epithelial surface and were present in the lamina propria.
Webster (1974)	animal experimentation	Baboons fed crocidolite showed small numbers of needles in ashed tissue of gut wall. No macroscopic lesions noted. No abnormalities and no evidence of peritoneal tumours or gastrointestinal tumours.
Westlake (1974)	animal experimentation	After 3 months on a diet of chrysotile and cellulose rat intestine showed no tumour development. Fibers were found in mucus of goblet cells, in cytoplasm of epithelial cells and in smooth muscle layers.
Westlake et al. (1965)	animal experimentation	Rats were fed chrysotile asbestos, and subsequent electron microscopy revealed asbestos crystals in the colonic epithelium and lamina propria. Particles appeared to migrate through mucus of goblet cells, into the cell itself and hence into the lamina propria
Wigle (1977)	human epidemiology	Excess mortality due to cancer of stomach and lungs in males, and pancreas in females, was observed in two municipalities with known high exposure. Absence of excess pancreatic cancer in males suggests that excess in females was not due to waterborne asbestos. Study did not reveal evidence of excess cancer mortality attributable to asbestos in drinking water.
Zaidi (1974)	perspective, animal experimentation	Roughage in food causes mucous secretions. Asbestos particles adhere to mucous and pass to lower intestine with no chance to penetrate. If mucous barrier broken, then possibly some effect could be seen.
Zaidi et al. (1976)	animal experimentation	How far ingested fibers will penetrate very strong mucous barrier, muscular and serosal layers of gastrointestinal tract needs further elucidation. The structure of the tract is morphologically different from that of the lung where fibers can pass easily through aveolar membranes. The significance of the gastrointestinal tract in the etiology of malignancies, if any, observed in asbestos workers may be attributable to soluable factors which pass out of dusts in the stomachs acidic environment.

7.0 ASBESTOS: ONGOING RESEARCH

1. Environmental Research Laboratory, Duluth, Minnesota. (Dr. P. Cook).

   Research is being conducted to determine the pathway of asbestos fiber uptake by fish. Previous studies have determined that asbestos fibers bioaccumulate in fish (lake trout) kidney tissue. No fibers were found in muscle tissue. It is presently thought that asbestos fibers are received via the food chain, and not by direct uptake from the water since fish held in fiber contaminated water, under laboratory conditions, do not accumulate fibers.

2. United States Department of Interior, Fish and Wildlife Service, Alaska. (H. Metsker).

   Water sampling and fish tissue analysis is being conducted to determine the presence of asbestos in the aquatic environment and biota. Investigations in 1979 established that fish muscle (burbot, long-nosed sucker) contained up to 60 x 10^6 fibers per pound of tissue. Tissue analysis was conducted by the Environmental Research Laboratory, Duluth, Minnesota.

   Pending investigations will determine asbestos fiber levels in a variety of fish species (grayling, pike, inconnu, whitefish, juvenile and adult salmon) from the Yukon River, where fiber concentrations in analysed water samples have reached 1000 x 10^6 fibers/litre. Studies are also being considered to determine the source and biological activity of "new" versus "old" asbestos fibers in the aquatic environment.

3. National Institute of Environmental Health Studies, Research Triangle Park, North Carolina. (Dr. R. Shapiro)

Studies concerning the biological effects of ingested asbestos are being conducted with large numbers of animals under laboratory conditions. These studies were designed to be sensitive to a 2 percent increase in cancer incidence in rats fed asbestos fibers in regular diets over their lifetime.

Resultant data on hamsters should be released after review and approval by NIEHS in June 1981. Rat data will not be available until January 1982.

8.0 LITERATURE CITED

Amacher, D.E., A. Alarif and S.S. Epstein. 1975. The dose-dependent effects of ingested chrysotile on DNA systhesis in the gastrointestinal tract, liver and pancreas of the rat. Environ. Res. 10:208-216.

Anderson, C.H. and J. MacArthur Long. 1976. Preliminary interim procedure for fibrous asbestos. Anal. Chem. Br. U.S. EPA. Environ. Research. Lab. College Station Rd., Athens, Georgia 30601.

Auerback, O., E.D. Hammond, I.J. Selikoff, V.R. Parks, H.D. Kaslow and L. Garfinkel. 1977. Asbestos bodies in lung parenchyma in relation to ingestion and inhalation of mineral fibers. Environ. Res. 14:286-304.

Beaman, D.R. and D.M. File. 1976. Quantitative determination of asbestos fiber concentrations. Anal. Chem. 48 (1):101-110.

Becking, G. 1981. Health and Welfare Canada; Ottawa. Personal Communication.

Bolton, R.E. and J.M.G. Davis. 1976. The short term effects of chronic asbestos ingestion in rats. Ann. Occup. Hyg. 19:121-128.

Brodeur, P. 1980. The Asbestos Hazard. N.Y. Academy of Sciences, New York, N.Y. 93p.

Brown, A. 1974. Lymphohematogenous spread of asbestos. Environ. Health. Persp. 9: 203-204.

Bryan J.E., C.E. Walker, R.E. Kendal and M.S. Elson. 1973. Freshwater aquatic ecology in Northern Yukon Territory. Fish. and Mar. Serv., Pac. Reg., Tech. Rept. No. 73-21. 64 p.

Carter, R.E. and W.F. Taylor. 1978. Identification of a particular amphibole asbestos fiber in tissues of persons exposed to a high oral intake of the mineral. Environ. Res. 21:85-93.

Chapman, D.W. and T.C. Bjornn. 1969. Distribution of salmonids in streams with special reference to food and feeding, p. 153-176. In T.G. Northcote (ed.) Symposium on Salmon and Trout in Streams. H.R. MacMillan Lectures in Fisheries. Univ. British Columbia, Vancouver, B.C. 388p.

Chatfield E.J. and M.J. Dillon. 1979. A national survey for asbestos fibers in Canadian drinking waters. Environ. Health Directorate. Health. Prot. Br. Rept-79-EHD-34.

Cook, P. 1981. Environmental Research Laboratory; Duluth, Minnesota. Personal Communication.

Cook, P.M., I.B. Rubin, C.J. Maggiore and W.J. Nicholson. 1976. X-Ray diffraction and electron beam analysis of abestiform minerals in Lake Superior waters. Proc. Inter. Conf. on Environ. Sensing and Assessment 34 (2):1-9.

Cook, P.M. and G.F. Olson. 1979. Ingested mineral fibers: elimination in human urine. Science 204:195-198.

Craig, P.C. and V.A. Poulin. 1975. Movements and growth of Arctic grayling (Thymallus arcticus) and juvenile Arctic char (Salvelinus alpinus) in a small Arctic stream, Alaska. J. Fish. Res. Bd. Can. 32(5):689-697.

Cunningham, H.M. and R.D. Pontefract. 1971. Asbestos fibers in beverages and drinking water. Nature 232:332-333.

Cunningham, H.M. and R.D. Pontefract 1973. Asbestos fibers in beverages, drinking water and tissues: their passage through the intestinal wall and movement through the body. J. Assoc. Off. Anal. Chem. 56(4):976-981.

Cunningham, H.M. and R.D. Pontefract. 1974. Placental transfer of asbestos. Nature 249:177-178.

Cunningham, H.M., C.A. Moodie, G.A. Lawrence and R.D. Pontefract 1977. Chronic effects of ingested asbestos in rats. Arch. Environ. Contam. Toxicol. 6:507-513.

Davis, J.M.G., R.E. Bolton and J. Garrett. 1974. Penetration of cells by asbestos fibres. Environ. Health Persp. 9:255-260.

Durham, R.W. and T. Pang. 1976. Asbestiform fiber levels in Lakes Superior and Huron. Environment Canada Pub. No. En36-502/67. Scientific Series No. 67, 12pp.

Environmental Protection Service. 1977. An environmental assessment of the effects of Cassiar Asbestos Corporation on Clinton Creek, Yukon Territories. Surv. Rept. No. EPS 5-PR-77-3. 38p.

Epstein, S.S. and M. Varnes. 1976. The short-term effects of ingested chrysotile asbestos on DNA synthesis in the pancreas and other organs of a primate. Experientia 32(5):602-604.

Fears, T.R. 1976. Cancer mortality and asbestos deposits. Am. J. Epidemiol. 104(5):523-526.

Gibel, W., K. Lohs, K.H. Horn, G. P. Wildner and F. Hoffman. 1976. Experimental study of cancerogenic activity of asbestos filter material following ingestion. Arch. Geschwulstforch. 46:437-442.

Glass, R.W. 1976. Improved methodology for determination of asbestos as a water pollutant. Ontario Research Foundation Report. April 30, 1976. Mississauga, Ontario, Canada.

Graham, J. and R. Graham. 1967. Ovarian cancer and asbestos. Environ. Res. 1:115-128.

Gross, P., R.A. Harley, L.M. Swinburne, J.M.G. Davis and W.B. Greene 1974. Ingested mineral fibers, do they penetrate tissue or cause cancer. Arch. Environ. Health. 29:341-347.

Hammond, E.C. and I.J. Selikoff. 1973. Relation of cigarette smoking to risk of death of asbestos-associated disease among insulation workers in the United States. In: Biological Effects of Asbestos. Bogovski et al. (eds), pp 312-317, International Agency for Research on Cancer, Lyon.

Harrington J.M., G.F. Craven, J.W. Meigs, P.J. Landrigan, J.T. Flannery and R.S. Woodhull. 1978. An investigation of the use of asbestos cement pipe for public water supply and the incidence of gastro-intestinal cancer in Connecticut, 1935-1973. Am. J. Epidemiol. 107(2):96-103.

Henderson, W.J., D.M.D. Evans, J.D. Davies and K. Griffiths. 1975. Analysis of particles in stomach tumours from Japanese males. Environ. Res. 9:240-249.

Health and Welfare Canada. 1980. Guidelines for Canadian drinking water quality, 1978. Dept. of Supply and Services, Canada Cat. No. H48-10/1978-E.

Health and Welfare Canada. 1980. Guidelines for Canadian drinking water quality 1978: Supporting documentation. Dept. Supply and Services, Canada. Cat. No. H48-10/1978-IE.

Jacobs, R., J. Humphreys, K.S. Dodgson and R.J. Richards. 1978. Light and electron microscope studies of the rat digestive tract following prolonged and short-term ingestion of chrysotile asbestos. Br. J. Exp. Path. 59:443-453.

Kanazawa, K., M.S.C. Birbeck, R.L. Carter and F. Roe. 1970. Migration of asbestos fibers from subcutaneous injection sites in mice. Br. J. Cancer. 24(1):96-106.

Kay, G.H. 1974. Asbestos in drinking water. J. Am. Water Works Assoc. 65:513-514.

Lawrence, J. and H. Walter Zimmerman. 1977. Asbestos in water. Mining and processing effluent treatment. Canada Center for Inland Waters, Burlington, Ontario pp. 156-160.

Lee, D.H.K. 1974. Biological effects of ingested asbestos: report and commentary. Environ. Health. Pers. 9:113-122.

Levy, B.S., E. Sigurdson, J. Mandel, E. Laudon and J. Pearson. 1976. Investigating possible effects of asbestos in city water: Surveillance of gastrointestinal cancer incidence in Duluth, Minnesota. Am. J. Epidemiol. 103(1):362-368.

Lishka, R.J., J.R. Millette and E.F. McFarren. 1975. Asbestos Analysis by Electron Microsocpe. Proc. AWWA Water Quality Tech. Conf. American Water Works Assoc., Denver, Colorado XIV - 1 - XIV - 12, 1975.

Masson, T.J., F.W. McKay and R.W. Miller. 1974. Asbestos-like fibers in Duluth water supply. Relation to cancer mortality. J. Am. Medical Assoc. 228(8):1019-1020.

McCrone, W.C. and I.M. Stewart. 1974. Asbestos. Americ. Lab. 6 (4):10-18.

McCullagh, S.F. 1980. Is there a risk to health in using asbestos-cement pipes for the carriage of drinking water? Ann. Occup. Hyg 23:189-193.

McDonald, J.C., A.D. McDonald, G.W. Gibbs, J. Siemiatycki and C.E. Rossiter. 1971. Mortality in the chrysotile asbestos mines and mills of Quebec. Arch. Environ. Health. 22.

McKinnon G.A. and F.N. Hnytha. 1978. A survey of the fish resources of Liard River tributaries as related to highway construction and operation, 1976-1977. Fish. and Mar. Serv. MS Rept., Dept. of Indian Affairs and Northern Development. 121 p.

McPhail J.D. and C.C. Lindsay. 1970. Freshwater fishes of Northwestern Canada and Alaska. Fish. Res. Bd. Can. Bull. No. 173.

Meigs, J.W., S.D. Walter, J.F. Heston, J.R.Millette, G.F. Craun, R.S. Woodhull and J.T. Flannery. 1980. Asbestos cement pipe and cancer in Connecticut 1955-1974. J. Environ. Health. 42(4):187-191.

Merliss, R.R. 1971. Talc-treated rice and Japanese stomach cancer. Science 173:1141.

Metsker, H. 1980. Investigations of contaminants found in fish and wildlife in Alaska during 1979. U.S. Dept of Int., Fish and Wildlife Serv. MS Report. 20p.

Metsker, H. 1981. U.S. Dept. of Interior, Fish and Wildlife Service, Anchorage, Alaska. Personal Communication.

Michaels, L. and S.S. Chissick. 1979. Asbestos Properties, Applications, and Hazards. Vol 1. John Wiley and Sons Ltd. Toronto.

Millette, J.R. and E.F. McFarren. 1976. EDS of Waterborne Asbestos Fibers in TEM, SEM and STEM. Scanning Electron Microscopy/1976 (Part III) 451-460, 1976.

Morgan, W.K.C. 1975. Danger from asbestos fibers in drinking water? Chest Physicians 14(3):12.

Mueller, P.K., A.E. Alcocer, R.L. Stanley and G.R. Smith. 1975. Asbestos Fiber Atlas. U.S. Environmental Protection Agency Technology Series, EPA 650/2-75-036.

Oliver, T. and L.E. Murr. 1977. An electron microscope study of asbestiform fiber concentrations in Rio Grande Valley water supplies. J. Am. Water Works Assoc. 69(8):428-431.

Olmsted W.R., T.L. Slaney and J.D. McPhail. 1979. Late winter and early summer fishery investigations: Shakwak Highway Improvement Project Construction Segments 2-6. Prep. by F.F. Slaney and Company Ltd. for Dept. of Public Works. 87 p.

Olmsted W.R., P.W. Delaney, T.L. Slaney and G.A. Vigers. 1980. Chinook salmon (Oncorhynchus tshawytscha). Fry and smolt enumeration/marking project, Nechako and Quesnel/Horsefly Rivers, B.C. Prep. by E.V.S. Consultants Ltd. for Dept. of Fisheries and Oceans, Vancouver. 126 pp + Appendix.

Oxberry, J.R., P. Doudoroff and D.W. Anderson. 1978. Potential toxicity of taconite tailings to aquatic life in Lake Superior. J. Water Poll. Control Fed. 50:240-251.

Peters, G.A. and B.J. Peters. 1980. Sourcebook on Asbestos Diseases. Garland Publishing Inc., New York.

Pooley, F. 1974. Locating fibers in the bowel wall. Environ. Health Persp. 9:235.

Pontefract, R.D. 1974a. Ingestion of asbestos. Canadian Res. and Dev. 21.

Pontefract, R.D. 1974b. Penetration of asbestos through the digestive wall in rats. Environ. Health. Persp. 9:213-214.

Reed R.J. 1964. Life history and migration patterns of Arctic grayling, Thymallus arcticus, (Pallas), in the Tanana River Drainage of Alaska. Alaska Dept. of Fish and Game. Res. Rept. No. 2:1-30.

Schneider, R.J. and R.R. Maurer. 1977. Asbestos and embryonic development. Teratology 15(3):273-279.

Schneiderman, M.A. 1974. Digestive system cancer among persons subjected to occupational inhalation of asbestos particles: a literature review with emphasis on dose response. Environ. Health. Resp. 9:307-311.

Sebastien, P., X. Janson, G. Bonnraud, G. Riba, R. Masse and J. Bignon. 1979. Translocation of asbestos fibers through respiratory tract and gastrointestinal tract according to fiber type and size. In: Dusts and Disease (Occupational and Environmental Exposures to Selected Fibrous and Particulate dusts). (Ed.) R. Lemen and J.M. Demont, Pathotox Pub. Inc.

Selikoff, I.J. 1974. Epidemiology of gastrointestinal cancer. Environ. Health Persp. 9:299-305.

Selikoff, I.J. 1977. Cancer risk of asbestos exposure. In: Origins of Human Cancer, Book C. C.S.H. Conf. on Cell Proliferation Vol. 4. (eds.) H. Hiah, J. Watson and J.Wilson. Cold Spring Harbour Laboratory. N.Y. pp. 1765-1784.

Selikoff I.J., J. Chung and E.C. Hammond. 1964. Asbestos exposure and neoplasia. J. Amer Med. Ass. 188:22-26.

Selikoff, I.J., E.C. Hammond and J. Chung. 1972. Carcinogenicity of amosite asbestos. Arch. Environ. Health. 25:183-186.

Selikoff, I.J. and D.H.K. Lee. 1978. Asbestos and Disease. Academic Press.

Selikoff, I.J. and E.C. Hammond (eds). 1979. Health Hazards of Asbestos Exposure. Ann. N.Y. Acad. Sci. Vol. 330.

Shapiro, R. 1981. National Institute of Environmental Health Studies, Research Triangle Park, North Carolina. Personal Communication.

Shreier H. and J. Taylor. 1980. Asbestos fibers in receiving waters. Inland Waters Directorate, Environment Canada. Technical Bulletin No. 117.

Shugar, S. 1979. Effects of asbestos in the Canadian environment. National Res. Council Canada. Rept. No. 16452.

Smith, W.E. 1973. Asbestos, talc and nitrates in relation to gastric cancer. Industrial Hygiene Summary Reports, May 1973.

Steigenberger L.W., G.J. Birch, P.G. Bruce and R.A. Robertson. 1974. Northern Yukon Freshwater Fisheries Studies 1973. Fish. and Mar. Serv., Pac. Reg., Tech. Rept. No. 74-20. 51 p.

Steigenberger, L.W., M.S. Elson, P.G. Bruce and Y.E. Yole. 1975. Northern Yukon Fisheries Studies, 1971-1974. Vol 2. Fish. and Mar. Serv., Pac. Reg., Tech. Rept. PAC/T-75-23.

Storeygard, A.R., and A.L. Brown Jr. 1977. Penetration of the small intestinal mucosa by asbestos fibers. Mayo Clinic Proc 52:809-812.

United States Environmental Protection Agency. 1976. Asbestos fibers in natural runoff and discharges from sources manufacturing asbestos products. Final Report Part II. EPA-560/6-76-020.

United States Environmental Protection Agency. 1977. Asbestos fibers in discharges from selected mining and milling activities. Final Report III. EPA-560/6-77-001.

United States Environmental Protection Agency. 1980. Ambient water quality criteria for asbestos. Rept. No. EPA 440/5-80-022.

Wagner, J.C. 1972. Current opinions on the asbestos cancer problem. Ann. Occup. Hyg. 15:61-65.

Webster, I. 1974. The ingestion of asbestos fibers. Environ. Health. Persp. 9:199-202.

Westlake, G.E. 1974. Asbestos fibers in the colonic wall. Environ. Health Persp. 9:227.

Westlake, G.E., H.J. Spjut and M.N. Smith. 1965. Penetration of colonic mucosa by asbestos particles. An electron microscopic study in rats fed asbestos dust. Lab. Invest. 14(11):2029-2033.

Wigle, D.T. 1977. Cancer mortality in relation to asbestos in municipal water supplies. Arch. Environ. Health 32(4):185-190.

Zaidi, S.H. 1974. Ingestion of asbestos. Environ. Health. Persp. 9:239-240.

Zaidi, S.H., G.S.D. Gupta, Q. Rahman, J.L. Kaw and R. Shanker. 1976. Early response of gastric mucosa to ingested asbestos dust and the dissolution of nickel. Environ. Res. 12:139-143.

APPENDIX I

GEE (MINNOW) TRAPPING DATA FROM SITES IN CLINTON CREEK, SEPTEMBER 1980

DATE	AREA	SITE	TEMP. (°C) IN	TEMP. (°C) OUT	SPECIES CHNK	GRAY	WTF	SUCK	COTT	COMMENTS
6/09	TS-1	1	7.5	7.0						
		2	"	"						
	TS-2	1	8.0	7.0	1					u/s of Br.
		2	"	"		1				d/s of Br.
	TS-3	1	7.0	6.5						
		2	6.5	5.5						
		3	"	"						
	TS-4	1	7.5	5.5						
		2	"	"						
		3	"	"						
	TS-5	1	5.0	4.5						
		EC	2.0	0.0						Eagle Cr.
	TS-7	1	6.5	4.0						
		2	"	"						
		3	"	"						
		4	"	"						
		5	"	"						
		6	"	"						
		7	"	"						
7/09	TS-1	1	7.0	7.0						
		2	"	"						
	TS-2	1	7.0	7.5		1				u/s of Br.
		2	"	"					1	d/s of Br.
	TS-3	1	6.5	7.0						
		2	5.5	6.5						
	TS-3	3	5.5	6.5	1					

APPENDIX I cont'd.

DATE	AREA	SITE	TEMP. (°C) IN	TEMP. (°C) OUT	SPECIES CHNK	GRAY	WTF	SUCK	COTT	COMMENTS
7/09	TS-4	1	5.5	5.0						
		2	"	"	1					
		3	"	"						
	TS-5	1	4.5	3.5						
		EC	0.0	0.0						Trap Frozen
	TS-7	1	4.0	3.5						
		2	"	"		1				
		3	"	"						
		4	"	"						
		5	"	"						
		6	"	"						
8/09	TS-1	1	7.0	7.0						
		2	"	"						
	TS-2	1	7.5	7.5						
		2	"	"						
		3	"	"	1					
	TS-3	1	7.0	7.0						
		2	6.5	6.5	1					
		3	"	"		1				
	TS-4	1	5.0	5.0						
		2	"	"						
		3	"	"						
	TS-5	1	5.0	5.0						
		2	3.5	4.0	1					
	TS-5	3	3.5	4.0	1					
	TS-6	1	3.5	4.0						
		2	"	"						
		3	"	"						
	TS-7	1	3.5	4.0						
		2	"	"						

APPENDIX I cont'd.

DATE	AREA	SITE	TEMP. (°C) IN	TEMP. (°C) OUT	SPECIES CHNK	SPECIES GRAY	SPECIES WTF	SPECIES SUCK	SPECIES COTT	COMMENTS
8/09	TS-7	3	3.5	4.0	1					
	TS-8	1	4.0	4.0						
		2	"	"						
		3	"	"						
9/09	TS-1	1	7.0	7.0						
		2	"	"						
		3	"	"						
	TS-2	1	7.5	7.0						
		2	"	"	2					
		3	"	"						
	TS-3	1	7.0	7.0						
		2	6.5	6.5	2					
		3	"	"						
	TS-4	1	5.0	5.5						
		2	"	"						
		3	"	"						
	TS-5	1	5.0	5.5		1				
		2	4.0	4.5						
		3	"	"						
	TS-6	1	4.0	4.5						Trap Destroyed
		2	"	"						
		3	"	"						
	TS-7	1	4.0	4.5						
		2	"	"						
		3	"	"						
	TS-8	1	4.0	4.5						
		2	"	"						
		3	"	"						

APPENDIX I cont'd.

DATE	AREA	SITE	TEMP. (°C) IN	TEMP. (°C) OUT	SPECIES CHNK	GRAY	WTF	SUCK	COTT	COMMENTS
10/09	TS-1	1	7.0	8.0						
		2	"	"						
		3	"	"						
	TS-2	1	7.0	8.0						
		2	"	"						
		3	"	"						
	TS-3	1	7.0	7.5						
		2	6.5	7.0						
		3	"	"	2					
	TS-4	1	5.5	6.5						
		2	"	"						
		3	"	"	1					
	TS-5	1	5.5	6.5						
		2	4.5	6.0						
		3	4.5	6.5						
	TS-6	2	4.5	6.0		1				
		3	"	"						
	TS-7	1	4.5	6.0						
		2	"	"	2					
		3	"	"	1					
	TS-8	1	4.5	6.0						
		2	"	"						
		3	"	"						

CHNK - Chinook
GRAY - Grayling
WTF - Whitefish
SUCK - Sucker
COTT - Sculpin
EC - Eagle Creek

APPENDIX II

ELECTROSHOCKING DATA FOR SELECTED AREAS OF CLINTON CREEK

DATE	SECTION	AREA	TEMP. (^{o}C)	SPECIES					COMMENTS
				CHNK	GRAY	WTF	SUCK	COTT	
5/09	6	Clinton Br.	6.5	4	1				
6/09	1	d/s of TS-1	7.0						
	1	u/s of TS-2	7.0	1	3				From deep pockets
8/09	1	Lower Canyon	8.0	2	12				
	2	d/s of TS-2	8.0	3	3				300 m shocked
	2	u/s of TS-3	7.5	1					100 m "
	2	d/s of TS-3	7.5						200 m "
	1	Mid Canyon	8.0		17				
9/09	2	Wolverine Cr.	3.5						
	3	TS-5 to TS-4	6.5	3	2				
	3	1 km d/s TS-5	7.0						200 m shocked
	4	u/s & d/s of TS-6	7.0	2	4				750 m shocked
10/09	1	Upper Canyon	8.0	1	2				
	2	1.5 km d/s TS-2	8.0	3	2				750 m shocked
	6	d/s Clinton Br.	7.0	1					150 m "
	6	u/s Clinton Br.	7.0	1					300 m "
	6	u/s Confluence	7.0	1					150 m "

u/s: Upstream
d/s: Downstream
CHNK - Chinook
GRAY - Grayling
WTF - Whitefish
SUCK - Sucker
COTT - Sculpin

APPENDIX III

SCALE SAMPLE DATA OF FISH SPECIES CAPTURED
FROM CLINTON CREEK WATERSHED, SEPTEMBER 1980

DATE	SPECIES	LENGTH (mm)	SECTION	METHOD	BOOK	SAMPLE	AGE
05/09	Chinook	72	6	ES	1	1	0+
	"	82	6	ES	1	2	0+
	"	75	6	ES	1	3	0+
	"	78	6	ES	1	4	0+
	Grayling	193	6	ES	1	5	2
	"	56	6	S	1	6	0+
	"	72	6	S	1	7	0+
	Whitefish	59	6	S	1	8	0+
	"	60	6	S	1	9	0+
	Chinook	88	2	MT	1	10	0+
	Grayling	142	2	MT	1	11	1+
06/09	Grayling	61	6	W	1	12	0+
	"	308	1	ES	1	13,14,15	6
	"	250	1	ES	1	16,17	4
	"	270	1	ES	1	18,19	5
	Chinook	77	1	ES	1	20	0+
	Grayling	172	6	W	1	22	2
07/09	Grayling	82	2	MT	1	21	1+
	"	77	6	MT	1	23	0+
	Chinook	82	3	MT	1	24	0+
	"	84	2	MT	1	25	0+
	Grayling	66	6	W	1	26	0+
08/09	Chinook	75	6	MT	1	27	0+
	"	93	3	MT	1	28	0+
	"	92	3	MT	1	29	0+
	Grayling	87	2	MT	1	30	0+
	Chinook	89	2	MT	1	31	0+
	"	95	2	MT	1	32	0+
	Grayling	360	Lake	GN	1	33,42	3
	"	284	Lake	GN	1	43,50	3
	"	310	Lake	GN	2	1,10	4
	"	210	1	ES	2	11,15	2
	"	238	1	ES	2	16,20	2
	"	223	1	ES	2	21,25	3
	Chinook	80	1	ES	2	26	0+
	Grayling	242	1	ES	2	27,30	3
	"	235	1	ES	2	31,35	3
	"	183	1	ES	2	36,40	2
	"	230	1	ES	2	41,45	4
	"	182	1	ES	2	46,50	2
	"	91	1	ES	3	1	0+
	"	90	1	ES	3	2	0+

APPENDIX III (cont.)

DATE	SPECIES	LENGTH (mm)	SECTION	METHOD	BOOK	SAMPLE	AGE
08/09	Grayling	102	1	ES	3	3	0+
	"	76	1	ES	3	4	0+
	Chinook	83	1	ES	3	5	0+
	Grayling	194	1	ES	3	6,10	3
	"	185	1	ES	3	11,15	2
	"	142	1	ES	3	16,20	1+
	"	232	1	ES	3	21,25	3
	"	182	1	ES	3	26,30	2
	"	175	1	ES	3	31,35	2
	"	245	1	ES	3	36,40	3
	"	200	1	ES	3	41,45	2
	"	220	1	ES	3	46,50	3
	"	140	1	ES	4	1,5	1+
	"	138	1	ES	4	6,10	1+
	"	182	1	ES	4	11,15	3
	"	175	1	ES	4	16,20	3
	"	133	1	ES	4	21,25	2
	"	170	1	ES	4	26,30	2
	"	140	1	ES	4	31,35	2
	"	149	1	ES	4	36,40	2
	"	247	2	ES	4	41,45	3
	"	184	2	ES	4	46,50	3
	"	82	2	ES	5	1	0+
	Chinook	88	2	ES	5	2	0+
	"	91	2	ES	5	3	0+
	"	82	2	ES	5	4	0+
	"	90	2	ES	5	5	0+
	Chinook	Adult*[1]		GN	5	6,15	5_2
	"	" *[1]		GN	5	16,25	5_2
09/09	Grayling	84	3	MT	5	26	0+
	Chinook	89	2	MT	5	27	0+
	"	85	2	MT	5	28	0+
	"	85	2	MT	5	29	0+
	"	85	2	MT	5	30	0+
	"	79	3	ES	5	31	0+
	"	88	3	ES	5	32	0+
	Whitefish	63	6	S	5	33	0+
	"	54	6	S	5	34	0+
	Grayling	75	6	S	5	35	0+
	"	41	6	S	5	36	0+
	"	57	6	S	5	37	0+
	"	62	6	S	5	38	0+
	"	82	3	ES	5	39	0+
	"	88	3	ES	5	40	0+
	Chinook	87	3	ES	5	41	0+
	Grayling	88	4	ES	5	42	0+
	"	76	4	ES	5	43	0+
	"	68	4	ES	5	44	0+
	"	72	4	ES	5	45	0+
	Chinook	82	4	ES	5	46	0+
	"	79	4	ES	5	47	0+

APPENDIX III (cont.)

DATE	SPECIES	LENGTH (mm)	SECTION	METHOD	BOOK	SAMPLE	AGE
10/09	Chinook	86	6	MT	5	48	0+
	"	85	6	MT	5	49	0+
	"	90	6	MT	5	50	0+
	Grayling	87	4	MT	6	1	0+
	Chinook	95	3	MT	6	2	0+
	"	85	2	MT	6	3	0+
	"	85	2	MT	6	4	0+
	Grayling	259	1	ES	6	5,10	6
	"	182	1	ES	6	11,15	2
	Chinook	87	1	ES	6	16	0+
	"	92	3	ES	6	17	0+
	"	88	3	ES	6	18	0+
	"	84	3	ES	6	19	0+
	Grayling	71	3	ES	6	20	0+
	"	84	3	ES	6	21	0+
	Chinook	71	6	ES	6	22	0+
	"	80	6	ES	6	23	0+
	"	76	6	ES	6	24	0+

ES = electroshocking
S = seining
MT = minnow trapping
W = weir
GN = gillnetting
*1 = adult chinook were captured in the Yukon River by local fishermen

APPENDIX IV: CLINTON CREEK WATER SAMPLING - SITE DESCRIPTIONS

Yukon River

Y-1:	Approximately 0.5 km above confluence of Forty Mile River and Yukon River.
Y-2:	Approximately 0.75 km below Forty Mile and Yukon River confluence.

Forty Mile River

FM-1:	Forty Mile River, approximately 1.0 km above confluence with Clinton Creek.
FM-2:	Approximately 1 km below confluence with Clinton Creek.

Clinton Creek

CC-1:	At head of Hudgeon Lake on mainstem Clinton Creek.
CC-2a:	Immediately below culverts at outlet of Hudgeon Lake.
CC-2b:	500 m below outlet of Hudgeon Lake, above small bridge on approach to mine site.
CC-3:	1 km (by road) above confluence of Eagle and Clinton Creek.
CC-4:	1 km (by road) below confluence of Eagle and Clinton Creek.
CC-5:	At Alou Bridge on road to Clinton Creek townsite.

Eagle Creek

EC-1:	10 m above mine access road.

Bear Creek

BC-1:	30 m above confluence with Hudgeon Lake.

Porcupine Creek

PC-1:	150 m above impoundment created by slumping overburden.

Wolverine Creek

WC-1:	60 m above confluence with impoundment caused by slumping tailings.
WC-2:	30 m above mine access road.

APPENDIX V: SUMMARY OF ASBESTOS FIBER ENUMERATION

Transmission Electron Microscopy with the Carbon Nucleopore Technique (condensed from: Anderson and Long 1976).

1.0 SCOPE AND APPLICATION

1.1 This method is applicable to drinking water and water supplies.

1.2 The method determines the number of asbestos fibers/liter, their size (length and width), the size distribution, and total mass. The method distinguishes chrysotile from amphible asbestos. The detection limits are variable and depend upon the amount of total extraneous particulate matter in the sample as well as the contamination level in the laboratory environment. Under favorable circumstances 0.1 million fibers/liter (MFL) can be detected. The detection limit for total mass of asbestos fibers is also variable and depends upon the fiber size and size distribution in addition to the factors affecting the total fiber count. The detection limit under favourable conditions is in the order of 0.1 ng/l.

2.0 SUMMARY OF METHOD

2.1 A variable, known volume of water sample is filtered through a membrane filter of sufficiently small pore size to trap asbestos fibers. A small portion of the filter with deposited fibers is placed on an electron microscope grid and the filter material removed by gentle solution in organic solvent. The material remaining on the electron microsope grid is examined in a transmission microscope at high magnification. The asbestos fibers are identified by their morphology and electron diffraction pattern, and their length and width are measured. The total area examined in the electron microscope is

determined and the number of asbestos fibers in this area are counted. The concentration in MFL is calculated from the number of fibers counted, the amount of water filtered, and the ratio of the total filtered area/sampled filter area. The mass/liter is calculated from the assumed density and the volume of the fibers.

3.0 SAMPLING

3.1 Containment Vessel

The sampling container should be a clean polyethylene, screw-capped bottle capable of holding at least one liter. The bottle should be rinsed at least two times with the water that is being sampled.

NOTE: Glass vessels are not suitable as sampling containers.

3.2 Quantity of Sample

A minimum of approximately one liter of water is required and the sampling container should not be filled. It is desirable to obtain two samples from one location.

3.3 Sample Preservation

No preservatives should be added during sampling and the addition of acids should be particularly avoided. If the sample cannot be filtered in the laboratory within 48 hours of its collection, sufficient amounts (1 ml/l of sample) of a 2.71% solution of mercuric chloride to give a final concentration of 20 ppm of Hg may be added to prevent bacterial growth.

4.0 PROCEDURE

4.1 Filtration

The separation of the insoluble material, including asbestiform minerals, through filtration and subsequent deposition on a membrane filter is a very critical step in the procedure. The objective of the filtration is not only to separate, but also to distribute uniformly the particulate matter such that discrete particles are deposited with a minimum of overlap.

The volume filtered will range from 50-500 ml. In an unknown sample the volume can not be specified in advance because of the presence of variable amounts of particulate matter. In general sufficient sample is filtered such that a very faint stain can be observed on the filter medium. The maximum loading that can be tolerated is 20 ug/cm^2, or about 200 ug on a 47-mm diameter filter; 5 ug/cm^2 is near optimum. If the total solids content is known, an estimate of the maximum volume tolerable can be obtained. In a sample of high solids content, where less than 50 ml is required, the sample should be diluted with filtered distilled water so that a minimum total of 50 ml of water is filtered. This step is necessary to allow the insoluble material to deposit uniformly on the filter. The filtration funnel assembly must be scrupulously cleaned before each filtration. The filtration should be carried out in a laminar flow hood.

4.2 Sample Drying

Remove the filter funnel and place the Nucleopore filter in a loosely covered petri dish to dry. The petri dish containing the filter may be placed in an asbestos-free oven at 45°C for 30 minutes to shorten the drying time.

4.3 Selection of Section for Carbon Coating

Using a small pair of scissors or sharp scalpel cut out a rectangular section of the Nucleopore filter. The minimum approximate dimensions should be 15 mm long and 3 mm wide. Avoid selection near the perimeter of the filtration area.

4.4 Carbon Coating the Filter

Tape the two ends of the selected filter section to a glass slide using "Scotch" tape. Take care not to stretch the filter section. Identify the filter section using a china marker on the slide. Place the glass slide with the filter section into the vacuum evaporator. Insert the necked carbon rod, and following manufacturer's instructions, obtain high vacuum. Evaporate the neck, with the filter section rotating, at a distance of approximately 7.5 cm from the filter section to obtain a 30-50 nm layer of carbon on the filter paper. Evaporate the carbon in several short bursts rather than continuously to prevent overheating the surface of the Nucleopore filter.

4.5 Preparation of Electron Microscope Grids

The preparation of the grid for examination in the microscope is a critical step in the analytical procedure. The objective is to remove the organic filter material from the asbestos fibers and a minimum loss and movement, with a minimum breakage of the grid support film.

4.6 Grid Transfer

Remove the filter from the vacuum evaporator and cut out three sections somewhat less than 3 mm x 3 mm, such that the square of Nucleopore fits within the circumference of the grid. Pass each of the filter sections over a static eliminator, then place each of the three

sections carbon-side down on separate specimen grids previously placed in the modified Jaffe Washer. Using a microsyringe, place a 10 µl drop of chloroform on each filter section resting on a grid, and then saturate the filter pad until pooling of the solvent occurs below the ridge formed by the glass slide inserted under the layer of filter papers. Place the cover on the petri dish and allow the grids to remain in the washer for approximately 24 hours. Do not allow the chloroform to completely evaporate before the grids are removed. To remove the grids from the washer, lift the screen support with the grid resting upon it and set this in a spot plate depression to allow evaporation of any solvent adhering to the grid. The grid is now ready for analysis or storage.

4.7 Specimen Preparation Laboratory

The ubiquitous nature of asbestos, especially chrysotile, demands that all sample preparation steps be carried out to prevent the contamination of the sample by air-borne or other source of asbestos. The prime requirement of the sample preparation laboratory is that it be sufficiently free from asbestos contamination that specimen blank determination using 200 ml of asbestos-free water yields no more than 2 fibers in twenty grid squares of a conventional 200 mesh electron microscope grid.

5.0 ELECTRON MICROSCOPIC EXAMINATION

5.1 Microscope Alignment and Magnification Calibration

Following the manufacturer's recommendations carry out the necessary alignment procedures for optimum specimen examination in the electron microscope. Calibrate the routinely used magnifications using a carbon grating replica.

5.2 Grid Preparation Acceptability

After inserting the specimen into the microscope adjust the magnification low enough (300X - 1000X) to permit viewing complete grid squares. Inspect at least 10 grid squares for fiber loading distribution, debris contamination, and carbon film continuity.

Reject the grid for counting if:

1) The grid is too heavily loaded with fibers to perform accurate counting and diffraction operations. A new sample preparation either from a smaller volume of water or from a dilution with filtered distilled water must then be prepared.

2) The fiber distribution is noticeably uneven. A new sample preparation is required.

3) The debris contamination is too severe to perform accurate counting and diffraction operations. If the debris is largely organic the filter must be ashed and redispersed. If inorganic, the sample must be diluted and prepared again.

4) The majority of grid squares examined have broken carbon films. A different grid preparation from the same initial filtration must be substituted.

5.3 Procedure for Fiber Counting

There are two methods commonly used for fiber counting. In one method (A) 100 fibers, contained in randomly selected fields of view, are counted. The number of fields plus the area of a field of view must

be known when using this method. In the other method (B), all fibers (at least 100) in several grid squares of 20 grid squares are counted. The number of grid squares counted and the average area of one grid square must be known when using this method.

NOTE 1: The method to use is dependent upon the fiber loading on the grid and it is left to the judgement of the analyst to select the optimum method. The following guidelines can be used: If it is estimated that a grid square (80 um x 80 um) contains 50-100 fibers at a screen magnification of 20000X it is convenient to use the filed-of-view counting method. If the estimate is less than 50, the grid square method of counting should be chosen. On the other hand, if the fiber count is estimated to be over 300 fibers per grid square, a new grid containing less fibers must be prepared (through dilution or filtration of a smaller volume of water).

Field-of-View Method

After determining that a fiber count can be obtained using this method, adjust the screen magnification to 10-20000X. Select a number of grid squares which would be as representative as possible of the entire analyzable grid surface. From each of these squares select a sufficient number of fields-of-view for fiber counting. The number of fields-of-view per grid square is dependent upon the fiber loading. If more than one field-of-view per grid is selected, scan the grid opening orthogonally in an arbitrary pattern which prevents overlapping of fields of view. Carry out the analysis by counting, measuring and identifying approximately 50 fibers on each of two grids.

Grid Square Method

After determining that a fiber count can be obtained using this method adjust the screen magnification to 10-20000X. Position of the grid square so that scanning can be started at the left upper corner of the

grid square. While carefully examining the grid, scan left to right, parallel to the upper grid bar. When the perimeter of the grid square is reached adjust the field of view up one field width and scan in the opposite direction. The tilting section of the fluorescent screen may be used conveniently as the field of view. Examine the square until all the area has been covered. The analysis should be carried out by counting, measuring and identifying approximately 50 fibers on each of two grids, or until 10 grid squares on each of two grids have been counted. Do not count fibers intersecting a grid bar.

6.0 MEASUREMENT AND IDENTIFICATION

Attempt to obtain a diffraction pattern of each fiber. Move the suspected fiber image to the center of the screen and insert a suitable selected area aperture into the electron beam so that the fiber image, or a portion of it, is in the illuminated area. The size of the aperture and the portion of the fiber should be such that particles other than the one to be examined are excluded from the selected area. If an incomplete diffraction pattern is obtained move the particle image around in the selected area to get a clearer diffraction pattern or to eliminate possible interferences from neighboring particles.

Determine whether or not the fiber is chrysotile or an amphibole by comparing the diffraction pattern obtained to the diffraction patterns of known standard asbestos fibers. Confirm the tentative identification or chrysotile and amphibole asbestos from their electron diffraction patterns.

7.0 CALCULATIONS

7.1 Fiber Concentrations

Grid Square Counting Method - If the Grid Square Method of counting is employed, use the following formula to calculate the total asbestos fiber concentration in MFL:

$$C = (F \times A_f) / (G \times A_g \times V_o \times 1000)$$

If ashing is involved use the same formula but substituting the effective filtration area of the 25 mm diameter filter for A_f instead of that for the 47 mm diameter filter. If one-half the filter is ashed, multiple C by two.

C = Fiber concentration (MFL).

F = number of fibers identified in "G" grid squares

A_f = effective filtration area of filter paper (mm^2) used in grid preparation for fiber counting

A_g = average area of one grid square (mm^2)

G = number of grid squares analyzed

V_o = original volume of sample filtered (ml)

Field-of-View Counting Method - If the Field-of-View Method of counting is employed use the following forumla to calculate the total asbestos fiber concentrations (MFL):

$$C=(F \times A_f \times 1000) / (A_v \times Z \times V_o)$$

If ashing is involved use the same formula but substituting the effective filtration area of the 25 mm diameter filter for A_f instead of that for the 47 mm diameter filter.

C = fiber concentration (MFL)

F = number of fibers identified in area examined ($A_v \times Z$)

A_f = effective filtration area of filter paper (mm^2) used in grid preparation for fiber counting

A_v = area of one field of view (μm^2)

Z = number of fields of view examined

V_o = original volume of sample filtered (ml)

7.2 Estimated Mass Concentration

Calculate the mass (μg) of each fiber counted using the following formula:

$$M = L \times W^2 \times D \times 10^{-6}$$

If the fiber content is predominantly chrysotile, the following formula may be used:

$$M = \frac{\pi}{4} \times L \times W^2 \times D \times 10^{-6}$$

Where: M = mass (μg)

L = length (μm)

W = width (μm)

D = density of fibers (g/cm^3)

Then calculate the mass concentration (μg/l) employing the following formula:

$$M_C = C \times \bar{M}_f \times 10^6$$

Where M_c = mass concentration (µg/l)

C = fiber concentration (MFL)

$\bar{M}_f$ = mean mass per fiber (µg)

To calculate $\bar{M}_f$ use the following formula:

Where: M = mass of each fiber, respectively

n = number of fibers counted

NOTE 1: Because many of the amphibole fibers are lath shaped rather than square in cross section, the computed mass will tend to be high since laths will in general tend to lie flat rather than on edge.

NOTE 2: Assume the following densities: Chrysotile 2.5, Amphibole 3.25.

8.0 PRECISION

8.1 Intra-Laboratory

The precision that is obtained within an individual laboratory is dependent upon the number of fibers counted. If 100 fibers are counted and the loading is at least 3.5 fibers/grid square, computer modeling of the counting procedure shows a relative standard deviation of about 10% can be expected.

In actual practice some deviation from this precision will be observed, but should not exceed ± 15% if several grids are prepared from the same filtered sample. The relative standard deviation of analyses of the same water sample in the laboratory will increase due to sample preparation errors and a relative standard deviation of about ± 25 - 30% will occur. As the number of fibers counted decreases, the precision will also decrease approximately proportional to N where N is the number of fibers counted.

8.2 Inter-Laboratory

While there have been numerous inter-laboratory testing programs, there have been few carried out using the procedure. Those that have been done indicate that agreement within a factor of two is achieved if 100 fibers can be counted.

9.0 ACCURACY

9.1 Fiber Concentrations

As no standard reference materials are available, only approximate estimates of the accuracy of the procedure can be made. At 1 MFL, it is estimated that the results should be within a factor of 10 of the actual asbestos fiber content.

This method requires the positive identification of a fiber to be asbestos as a means for its quantitative determination. As the state-of-the-art precludes the positive identification of all of the asbestos fibers present, the results by this method, as expressed as MFL, will be biased on the low side, and assuming no fiber loss, represent .2 - .6 of the total asbestos fibers present.

9.2 Mass Concentrations

As in the case of the fiber concentrations, no standard samples of the size distribution found in water are available. The accuracy of the mass determination should be somewhat better than the fiber determination because a larger fraction of the large fibers, which contribute the major portion of the mass, are identifiable. This will reduce the bias of low results due to difficulties in identification. At the same time, the assumption that the thickness of the fiber equals the width will result in a positive error in determining the volume of the fiber and thus give high results for the mass.