Environment Canada
Environmental Protection Service
Pacific Region
Yukon Branch

BASELINE STUDY OF THE WATERSHED IN THE IONA SILVER AREA, YUKON TERRITORY

Regional Program Report 84-04

by

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ABSTRACT

A survey of water quality and biological conditions in the streams on the Iona Silver Mine Ltd. property was carried out in July 1981. The purpose of the study was to obtain baseline data on water, sediment and biological conditions for use as comparison standards when evaluating future mining development in the area. The water and sediment chemistry in the lower reaches of Cache Creek reflect the characteristics of and appear to be influenced by groundwater drainage from mineralized areas. The quality criteria of the water downstream from the mixing zone of Cache Creek on the Ketza River shows no impact on the environment.

RÉSUMÉ

Une analyse de la qualité et des conditions biologiques des cours d'eau de la propriété de la Iona Silver Mine Ltd., a été effectuée au mois de juillet 1981. Le but de cette étude fut d'obtenir des données de base sur l'eau, les sédiments et les conditions biologiques comme référence pour comparer avec l'évaluation des futurs développements miniers dans la région. La chimie de l'eau et des sédiments de la partie en aval du ruisseau Cache réflète les caractéristiques et l'influence des sources souterrainnes drainant la région minéralisée. Les critères de qualité des eaux en aval de la zone de brassage des eaux de la riviere Ketza et du ruisseau Cache, indiquent aucun impact sur l'environnement.

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1 INTRODUCTION

A survey of water quality, sediment composition and biological conditions was conducted July 29-31, 1981 in the Ketza River watershed at Iona Silver Mines Ltd. claims southeast of the town of Ross River (Figures 1 and 2). The purpose of the survey was to obtain baseline information on the environmental quality of streams draining an area known to contain silver-lead ore deposits.

1.1 Background

The first recorded observations of silver-lead mineralization in the area was made in 1946 by prospectors working for the Hudson Bay Mining and Smelting Company. In 1955 further work was carried out in the area by Conwest Exploration Ltd. Between 1965 and 1969 Silver Key Mines and Stump Mines carried out geochemical surveys and undertook further undergound development.

Since 1972 Iona Silver Mines or its principals have acquired the rights to all of the known important silver-lead veins and other mineral occurrences in the area. Iona initiated, in 1977, an exploration program that included geological mapping, geochemical sampling and trenching. This exploration program continued through to 1980 and included further geochemical sampling, diamond drilling and underground development. During the period since initial observations of silver-lead mineralization were made, seven adits have been developed on the 90 mineral claims which Iona Silver Mines Ltd. controlled in 1981 (Figure 2). The more recent development work has concentrated on the K18B and A1 adits in which reserves are estimated for each at 55,000 tons grading 17 ounces per ton silver and 12% lead (Hicks, 1979, Sadlier-Brown and Nevin, 1978, DIAND, 1981).

During 1979 and 1980 Iona Silver Mines Ltd. consultants met with various government officials to explain the project and indicate the potential for mine development. The proposed mine/mill complex would operate on a year-round basis at a nominal rate of 100 tons per day. Of the ore processed, it is expected that 90% would be from A1

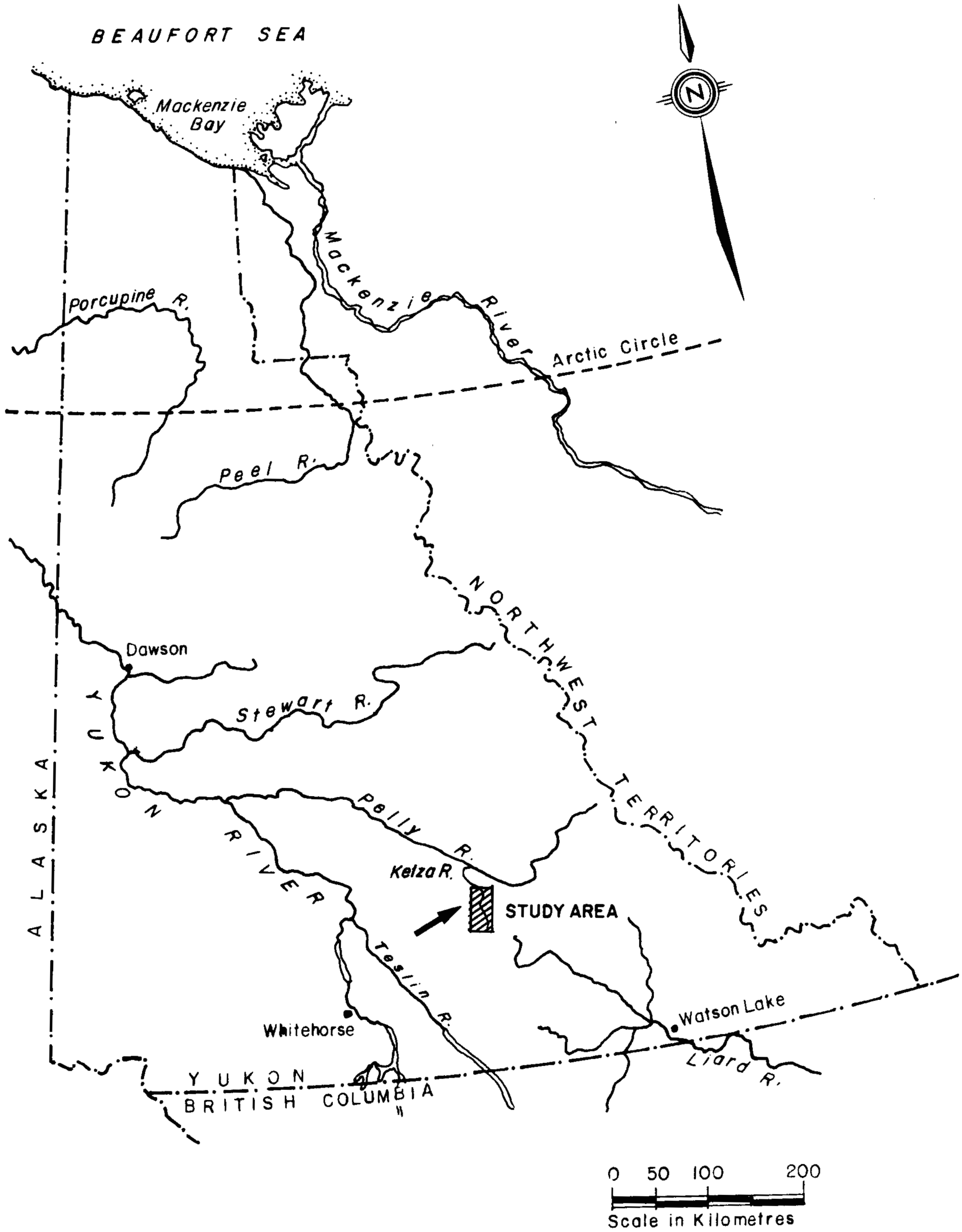

FIGURE 1 LOCATION OF IONA SILVER STUDY AREA

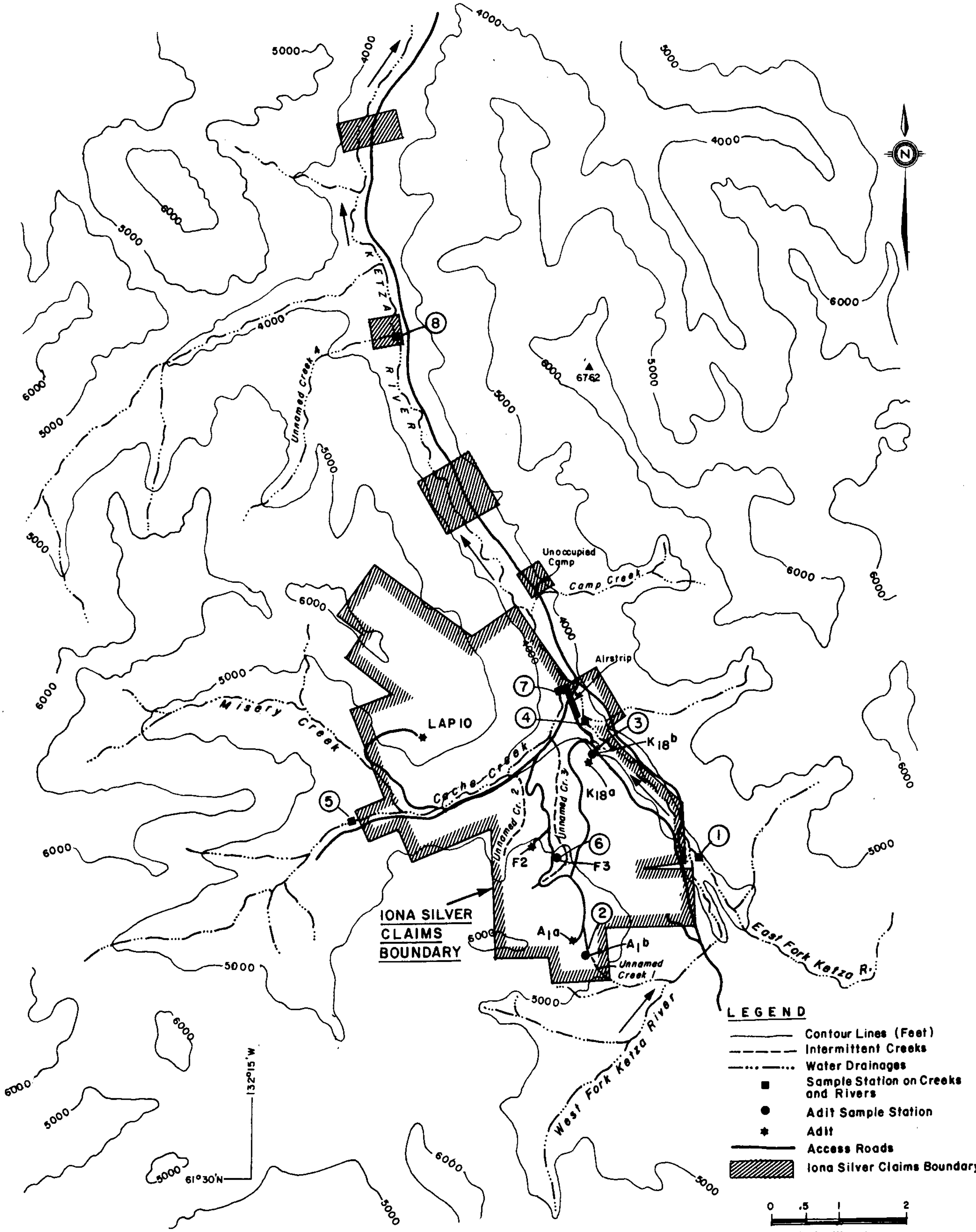

FIGURE 2 IONA SILVER STUDY AREA SHOWING DRAINAGES, MINERAL CLAIMS, ADITS AND SAMPLE STATIONS

and 10% from K18B and possible future development of other deposits at Lap 10, F3. The K18B and A1 adits are located at elevations of 3700 ft. and 5300 ft. respectively and exhibit water discharge at certain times of the year.

Preliminary investigations have identified areas near the confluence of Cache Creek with the Ketza River as the preferred mill and tailings pond locations although no detailed geotechnical work has been completed to date.

Iona has indicated that an environmental evaluation of the project and additional geotechnical work will be undertaken prior to further development. No progress on further environmental, geotechnical work or mill/mine development occurred during 1981.

The geology of the area has been summarized by Hicks (1979) as follows:

> "The property lies within an area of deformed and sedimentary rocks ranging in age from Proterozoic to Mississipian and comprising essentially a complex depositional basin which has been severely modified by tectonic processes including intrusion, volcanism, faulting, folding and hydrothermal activity. Dominant structural features are four major faults which shape the area geologically.
>
> Probably subsidiary to these main faults are faulting and fracturing on a local scale which, combined with hydrothermal activity, have produced sulphide bearing veins of economic interest...... They appear to cut virtually all rock types, although by analogy with similar deposits elsewhere, it may be anticipated that certain host rocks will be more favourable than others. The gangue is essentially siderite, accompanied by quartz and calcite.
>
> The veins contain shoots of massive to near-massive argentiferous galena, associated with freibergite and minor pyrite...... In addition to the normal mode of occurrence,

massive galena may form veins in the wallrock without siderite gangue and in other cases disseminated galena and freibergite occur within siderite.

In addition to the veins there is evidence of at least one occurence which may represent a bedded sulphide deposit carrying significant silver and lead."

2 STUDY AREA

The study area is centred at approximately 132° 12'W longitude and 61° 32'N Latitude near the junction of the Ketza River and Cache Creek on the north slopes of the Pelly Mountains. It is 48 km, by air, south of the community of Ross River and is accessible via the Campbell Highway and a 40 km access road which borders the Ketza River (Figure 1).

The area lies within the Pelly Mountains Ecoregion (Oswald and Senyk, 1977) which is characterized by elevations of up to 2400 metres and a typical relief of up to 1500 metres. The climate of the ecoregion is characterized by a mean annual precipitation of 625mm, more at higher elevations, and a mean annual temperature of -4°C to -6°C. The major valley bottoms are generally deeply mantled with glaciofluvial and morainal materials and locally ponded fine-textured lacustrine sediments. Bedrock outcrops are abundant on the ridges but generally obscured by talus on the lower slopes. The vegetation is characterized by open growing black and white spruce in valleys or on lower slopes. Lodgepole pine is common in areas that have been burned over and balsam poplar and aspen are present on warmer flood plains in the valley bottom. The tree line occurs between 1350m to 1500m above sea level. Although the general area lies in the discontinuous permafrost zone (Oswald and Senyk, 1977) permafrost was routinely encountered during exploration trenching (Hicks, 1979).

Samples were taken at eight locations in the Ketza River and Cache Creek drainages at elevations between 1075m and 1675m. The location of the sample stations is shown in Figure 2 and described in Table 1. Photographs of Stations 1 to 8 are illustrated in Figures 3 to 10.

TABLE 1 DESCRIPTION OF SAMPLE SITES IN THE IONA SILVER STUDY AREA

STATION	LOCATION	STREAM BOTTOM	REMARKS
1	61°33'N 132°08'W on the east fork of the Ketza River near its confluence with the west fork. Upstream of all Iona Silver activity and 3.8 km upstream of the Ketza River access bridge. Elevation 3980 ft (1213 m).	Medium rounded gravel mixed with fine sand. Some organic sediments in quiet areas.	Braided water course with willows and some spruce. Stable stream banks. River appears suitable for fish habitat, but beaver dams down stream may impede upstream movement. 0% shade.
2	61°32'N 132°09'W at the Al_b adit near the southern boundary of the Iona claims. Water from the adit drains southeast into Unnamed Creek 1 to the west fork of the Ketza River. Elevation 5300 ft (1614 m).	Fractured gravel packed with silt in an area disturbed by mine adit development. Water course was coloured with orange precipitate. 10% of the gravel was discarded from the sediment sample.	No vegetation in the immediate vicinity. Flow is likely frozen in the winter. No fish access to this area. Not suitable for bottom fauna. 0% shade.
3	61°34'N 132°09'W at the $K18_b$ adit 1 km upstream from the Ketza River access bridge. Adit drains east into the Ketza River upstream of its confluence with Cache Creek. Elevation 3950 ft (1204 m).	Silt to gravel in area disturbed by mine adit development.	Spruce and buckbrush in undisturbed areas. No fish access to this area. Flow is likely frozen in the winter. Not suitable for bottom fauna. 0% shade.
4	61°34'N 132°09'W on the Ketza River 0.7 km upstream of the Ketza River access bridge and upstream of its confluence with Cache Creek. Elevation 3900 ft (1189 m).	Cobbles to gravel in fast sections with silts deposited in Beaver ponds.	Water, sediment and bottom fauna samples were not collected but 4 grayling (Thymallus arcticus) were collected for metal analysis.

TABLE 1 DESCRIPTION OF SAMPLE SITES IN THE IONA SILVER STUDY AREA (continued)

STATION	LOCATION	STREAM BOTTOM	REMARKS
5	61°33'N 132°13'W on Cache Creek at the western boundary of the Iona Silver Property. Located 1.9 km upstream of its confluence with Misery Creek and 3.75 km upstream from its confluence with the Ketza River. Elevation 4200 ft (1280 m).	Medium to large gravel interspersed with fine sediments and sand. 20% - 50% gravel discarded from the sediment sample.	Banks are stable and covered with grasses and willows. Looks like good fish habitat but electrofishing results for 150 m was negative. 0% shade.
6	61°33'N 132°10'W at the F_3 adit which drains into Unnamed Creek 3, then north into Cache Creek 2 km upstream from Cache Creek's confluence with the Ketza River. Elevation 5100 ft (1555 m).	Crushed shale and fine sediments in area disturbed by mine adit development. 80% gravel discarded from the sediment sample.	No vegetation in disturbed areas. Alpine, fir, willow and grasses in undisturbed locations. Flow is likely frozen in the winter. Not suitable for bottom fuana. No fish access to the water. 0% shade.
7	61°34'N 132°09'W on Cache Creek, close to its confluence with the Ketza River. Access from the north end of the Iona Silver airstrip. Elevation 3700 ft (1127 m).	Small boulders to small rocks mixed with sediments. 95% of the gravel was discarded from the sediment sample.	Banks are stable and covered with grasses, willows and spruce. Six slimy sculpins (<u>Cottus cognatus</u>) were collected for metals analysis by electrofishing. 0% shade.
8	61°37'N 132°12'W on the Ketza River just upstream of its confluence with Unnamed Creek 4. Located on the Iona Silver camp claim 1, 7.6 km downstream of the Ketza River access bridge and all Iona Silver activities. Elevation 3480 ft (1060 m).	Large rocks to medium boulders to silt bottom in back eddies. Sediment samples were taken on a gravel bar representative of 20% of the stream bed.	Well defined creek banks with spruce and willow. Not suitable for electrofishing although it appears to be an excellent fish habitat. 0% shade.

FIGURE 3 STATION #1. ON EAST FORK OF KETZA RIVER UPSTREAM OF ALL IONA SILVER ACTIVITY.

FIGURE 4 STATION #2. LOWER A1 ADIT ($A1_b$). LOCATED 25m DOWNHILL FROM ADIT $A1_a$. ADIT WATER DRAINS EAST VIA UNNAMED CREEK 1 TO THE WEST FORK OF THE KETZA RIVER.

FIGURE 5 STATION #3, LOWER K18 ADIT ($K18_b$) 50m BELOW $K18_a$. LOCATED 1km UPSTREAM FROM THE KETZA RIVER ACCESS BRIDGE. ADIT WATER DRAINS TO THE EAST INTO KETZA RIVER VIA A SHORT UNNAMED CREEK.

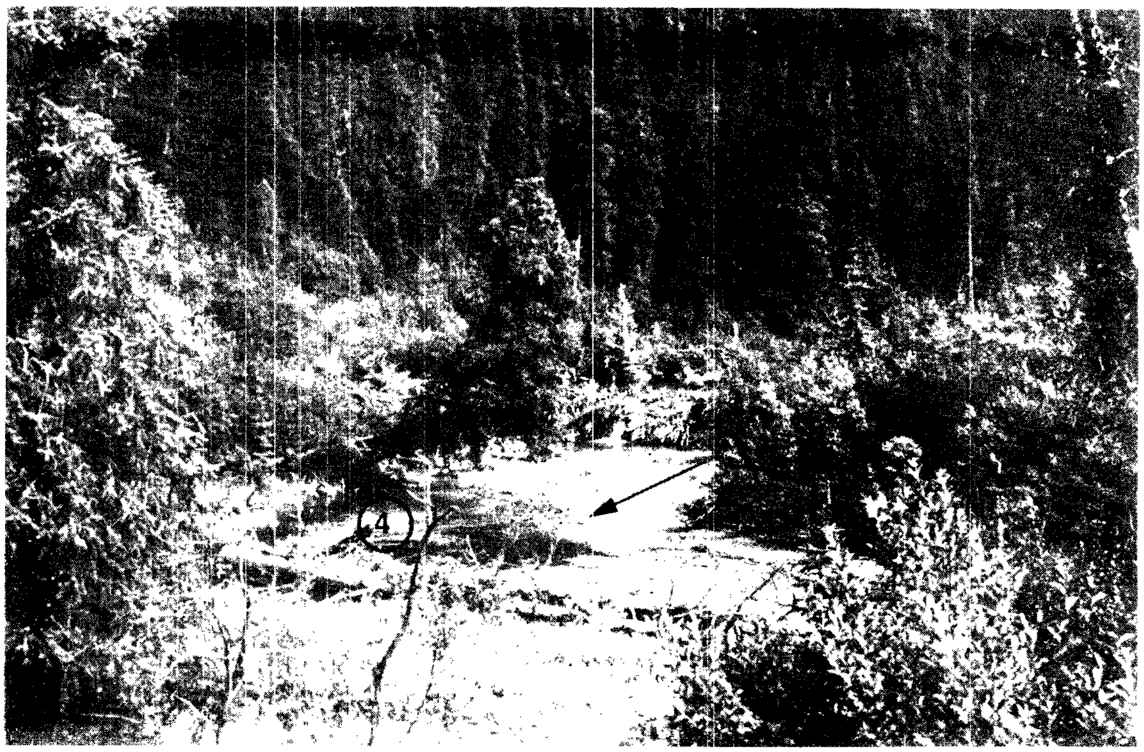

FIGURE 6 STATION #4 LOCATED ON THE KETZA RIVER 0.7km UPSTREAM FROM THE KETZA RIVER ACCESS BRIDGE. NOTE THE BEAVER DAM IMPEDING WATER FLOW.

FIGURE 7 STATION #5. LOCATED ON CACHE CREEK AT THE WESTERN BOUNDARY OF THE IONA SILVER CLAIMS UPSTREAM OF ALL IONA SILVER ACTIVITY.

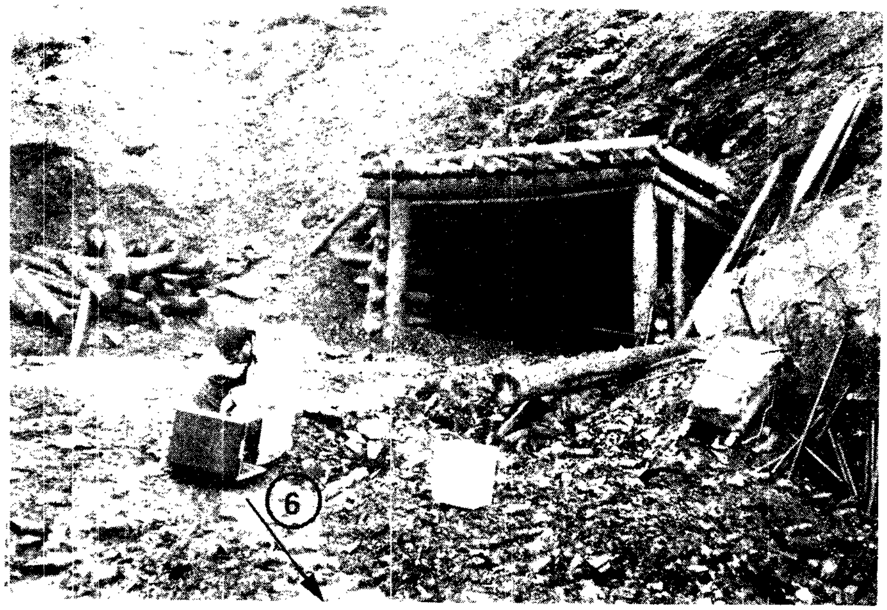

FIGURE 8 STATION #6. MOUTH OF F_3 ADIT. WATER DRAINS INTO UNNAMED CREEK 3 AND THEN TO CACHE CREEK.

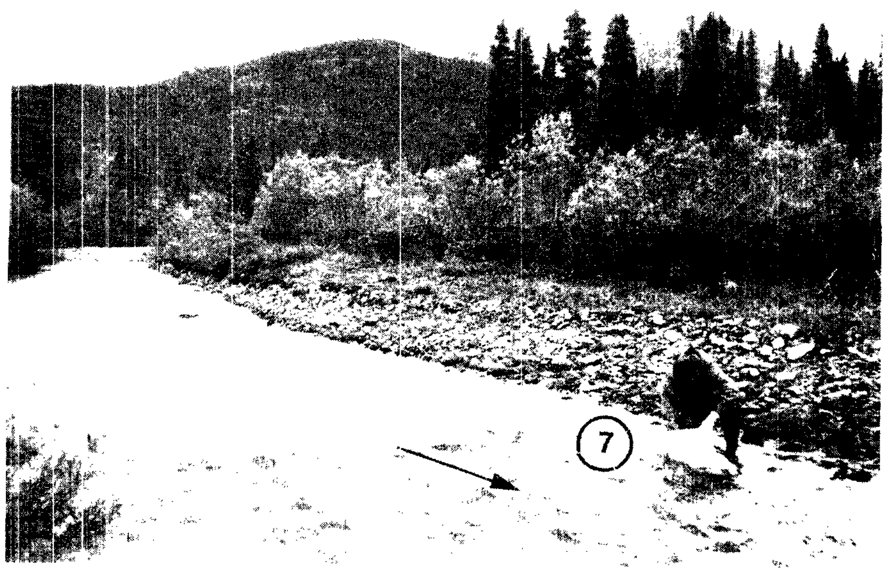

FIGURE 9 STATION #7 ON CACHE CREEK CLOSE TO ITS CONFLUENCE WITH THE KETZA RIVER. VIEW UPSTREAM.

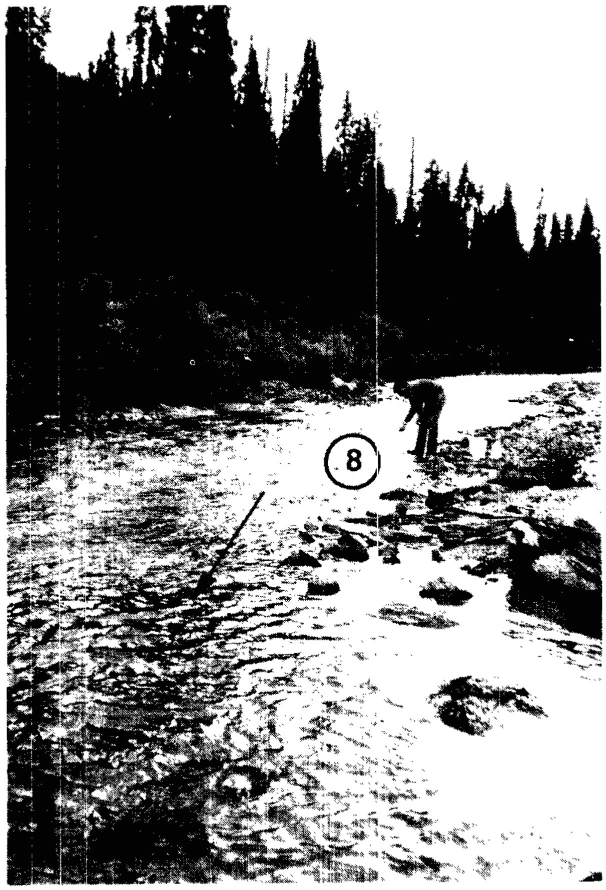

FIGURE 10 STATION 8. ON KETZA RIVER LOOKING UPSTREAM AT CAMP CLAIM #1, DOWNSTREAM OF ALL IONA SILVER ACTIVITY.

3 METHODS

Sampling was done once at each sample location during the period of July 29-30, 1981. All sample sites had road access although at the time of sampling Station 2 was not accessible by vehicle. Sampling at Station 4 was limited to collection of fish for tissue metal analysis.

3.1 Water Quality

The methods of collection and preservation for water samples are summarized in Appendix I, Table 1. Field measurements included temperature, pH, conductivity and flow estimates.

Samples were collected for laboratory analysis of dissolved oxygen, conductivity, ammonia, colour, turbidity, non-filterable residue (NFR), filterable residue (FR), total alkalinity, total phosphate, nitrite, nitrate, sulphate, chloride, cyanide, total silica, total mercury, total hardness and the following extractable metals:

Aluminum (Al)	Copper (Cu)	Selenium (Se)
Antimony (Sb)	Iron (Fe)	Silver (Ag)
Arsenic (As)	Lead (Pb)	Sodium (Na)
Barium (Ba)	Magnesium (Mg)	Strontium (Sr)
Beryllium (Be)	Manganese (Mn)	Tin (Sn)
Cadmium (Cd)	Molybdenum (Mo)	Titanium (Ti)
Calcium (Ca)	Nickel (Ni)	Vanadium (V)
Chromium (Cr)	Potassium (K)	Zinc (Zn)
Cobalt (Co)		

The laboratory analyses, with the exception of dissolved oxygen levels which were done in the Whitehorse laboratory, were sent to the Environmental Protection Service Regional Laboratory in West Vancouver.

The percent dissolved oxygen saturation was calculated by first determining the dissolved oxygen saturation from the formula:

$$S' = S \frac{P}{760} \text{ (APHA et al 1980)}$$

where S' = dissolved oxygen (DO) saturation concentration at the in situ temperature and atmospheric pressure

S = dissolved oxygen (DO) saturation concentration at sea level for in situ temperature

P = atmospheric pressure in mm of mercury (mm Hg) at site elevation

The percent dissolved oxygen saturation was obtained by using the ratio of field dissolved oxygen and S' in the following formula:

$$\frac{\text{Field DO}}{S'} \times 100 = \text{\% DO Saturation}$$

where Field DO = Dissolved Oxygen concentration measured in the field

All the data of water quality are given in Appendix II.

3.2 Sediments

Sediment samples were taken in triplicate at each station. The samples were shipped to the Environmental Protection Service, Laboratory Service, 4195 Marine Drive, West Vancouver, B.C. for leachable metals and particle size analysis.

A description of the sediment collection, preparation and analysis methods is given in Appendix I Table 2 while the results of the analysis are given in Appendix III Table 1 and 2.

3.3 Bottom Fauna

The bottom fauna samples were collected in triplicate with a Surber sampler. The collection, preservation and identification methods are given in Appendix I Table 3.

To statistically evaluate the invertebrate data collected, indices of diversity and evenness were calculated using the formulae described by Pielou (1975).

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

where: $P_i = n_i/N$

n_i = total number of individuals in the ith genus in one sample

N = total number of individuals identified to genus and/or species taxonomic level at one station

n = total number of genera collected at one station

$$\text{Evenness } (J') = H'/\log n$$

A description of the taxonomic groups is given in the Appendix IV Tables 1 and 2.

3.4 Fish

Fish collection was be means of a Smith-Root Type VIII Electrofisher in which electroshocking was done for a distance of 150-200 m at suitable stations. Some stations were not considered as potential fish habitat because of steep gradients or inadequate flow and therefore not sampled.

Dorsal muscle tissue was removed from the fish collected, kept frozen in plastic bags and sent to the Environmental Protection Service Regional laboratory in West Vancouver for analysis of fish tissue metals. The preparation involves the freeze drying and grinding of the tissue to obtain a homogeneous mixture, which was then subjected to low temperature ashing and dilute acid to digest the organic material. The analysis was then performed using the Inductively Coupled Argon Plasma (ICAP) combined with optical Emission Spectrometer.

The fish used for the analysis were arctic grayling (*Thymallus arcticus*) and slimy sculpin (*Cottus cognatus*). The results are shown in Appendix V.

4 RESULTS AND DISCUSSION

4.1 Water Quality

The area sampled is drained by Cache Creek and the Ketza River into which many small intermittent streams drain. At least a small portion of the flow in Ketza River and Cache Creek is contributed by groundwater flow from mine adits. Stations 2, 3 and 6 are located at adits and had groundwater flows of approximately 0.0026 m^3/s, 0.0013 m^3/s and 0.008 m^3/s respectively. The Ketza River is shallow at Station 8 and has an estimated flow of 2.51 m^3/s. There is no data to show relative contribution to the flow from surface or groundwater drainage however because of the mountainous terrain and high snow pack it is thought that surface runoff is the greatest contributor during the open water period.

The temperature of the water clearly indicates which water comes from surface locations and which comes from underground sources. Stations 2, 3 and 6 have temperatures of 2° and 4° C at the end of July while the other stations have temperatures between 9° and 11° C at the same time which indicates the warming effect during surface runoff.

The percent dissolved oxygen saturation ranges from 87% to 91% except at Station 3 where the saturation is 78%. All the dissolved oxygen levels are greater than 8.0 mg/l. The pH is rather basic, ranging from 8.2 to 8.4 as measured in the laboratory. The colour is 5 colour units or less and the turbidity is less than one except for Station 2 where it was 1.9 FTU. This level of 1.9 is not considered high and may have been created by bottom disturbance during sampling.

Conductivity values are seen to be highest at stations where groundwater discharge at an adit was sampled. Stations 2, 3 and 6 had field conductivity values of 550, 438 and 340 umhos/cm respectively which are consistently greater than at other stations. The conductivity values reflect the amount of dissolved solids (filterable residue) in water and the values for filterable residues found in this study follow a similar pattern. The values for filterable residue are 712, 542 and 438 mg/l at stations 2, 3 and 6 respectively. At these same stations the hardness of water is very high, ranging between 324 and 551 mg/l as $CaCO_3$. At stations 1, 5, 7 and 8 values were much lower for filterable residues (213-251 mg/l) and hardness (174-202 mg/l as $CaCO_3$). These values for hardness are considered above the acceptable limits for drinking water (Health and Welfare, 1978). High hardness values have been shown to reduce the toxicity of heavy metals to fish, (EPA, 1972) and Berube and Gilbert (1971) have reported that fish develop more slowly in hard water. Total alkalinity values follow the same general pattern as hardness, filterable residue and conductivity with the stations at flowing mine adits showing highest values with generally lower values at stations on Cache Creek and Ketza River. Values at these stations (stations 1, 5, 7 and 8) ranged from 124-187 mg/l which is well above the minimum level (20 mg/l) considered adequate for aquatic life (Thurston, et al, 1979).

Phosphorus was below the detection limit of .005 mg/l in every station. The amount of nitrite was below the detection limit in every station (<0.005 mg/l) except for Station 3 where the amount was 0.015 mg/l. The amount of nitrate was less than .05 mg/l at every station. The low values of phosphorus and nitrates may limit productivity.

The amount of sulfate varied according to the origin of the water supply. The surface waters contained sulphates in a range of 30.9 mg/l to 68.8 mg/l which is normal in natural conditions. The groundwater at mine adits showed a high content of sulphate which contributed to increases in the filterable residue content. At Station 2 the level was 238 mg/l, 162 mg/l at Station 6 and 115 mg/l at Station 3. This high sulfate level is probably due to oxidation of the sulfide deposit which contains lead and silver. Mining and processing of these ores to extract the metals may result in significant acid generation in the tailings from oxidation of sulphides to sulphates.

At all stations, the cyanides are below the detection limit of 0.03 mg/l. The average concentration of chloride in natural fresh water is 8.3 mg/l (Wetzel, 1975) and the water at Iona Silver property doesn't contain more than 1.4 mg/l.

The detection limit for silver (0.03 mg/l) is much higher than the recommended level for aquatic life (0.0001 mg/l) (Inland Waters Directorate, 1980) therefore no accurate assessment of potential impacts can be made except to note it was below detection limits at all stations. The same problem occurs with cadmium and selenium. Aluminum levels were within the recommended levels for aquatic life (Ontario Ministry of Environment, 1978) and it is not considered a problem with respect to drinking water. Arsenic levels are all within the recommended level (0.05 mg/l) for aquatic life and drinking water. The values for cobalt, chromium, mercury, molybdenum, nickel, strontium, tin, titanium and vanadium are all below detection limit and below recommended levels for drinking water and within acceptable levels for aquatic life where such levels have been specifically established. At Station 6, lead is present at 0.025 mg/l and zinc is present at 0.059 mg/l. The recommended levels for aquatic life are .01 mg/l for lead and .03 mg/l for zinc (Inland Waters Directorate, 1980).

4.2 Sediment

4.2.1 Sediment Particle Size Analysis. The particle size analysis results shown in Appendix III Table 2 are based on the materials sieved in the lab. During field collection the larger gravel, cobbles and boulders were removed during sampling. The results therefore generally show a lower percentage of coarse materials (>500 um) than actually exists in situ. This may also be true for the fine materials which become suspended in water during sampling and are lost downstream. The data presented in Appendix III Table 2 illustrate that there is considerable variation among the replicate samples at specific stations which reflects the variability encountered and the problems associated with obtaining truly representative sediment samples. Station 6 is seen to have a relatively higher percentage of fine silts and clays than the other stations. The results obtained for metal contents of the sediments is based on the fraction of the sediment sample that is smaller than 150 um. Considering the texture composition of the sediment samples and taking an average of the three replicates at each station the percentage of the total sediment sample analyzed for metals content from the stations, varies from 2.4% at Station 7 to 43.9% at Station 6.

4.2.2 Sediment Metal Analysis. The results of analysis for metals and cyanide levels in the sediments are presented in Appendix III Table 2.

Background levels for arsenic have been reported for many areas by numerous authors and considerable variation is seen in natural background levels. At Iona Silver the highest levels occur at Station 3 (563 mg/kg), Station 5 (248.3 mg/kg), Station 7 (185.33 mg/kg) and Station 8 (121.66 mg/kg). Frye (1973) suggested that for Lake Michigan 8 mg/kg can be considered as background. Hamence (1967) suggested that sediment levels of arsenic greater than 75 mg/kg should be considered exceptional. The levels identified here would be considered exceptional by Hamence however the sediments being sampled are in a heavily mineralized area that has some arsenic compounds associated with ore bodies so one would expect elevated levels to exist.

Frye (1973) has suggested a background level of 40 ppm is normal for chromium. This level is exceeded in the current study at Station 1 (59.6 mg/kg) and Station 3 (49.6 mg/kg). In a study by Mathers et al (1981) three of seven Yukon streams studied had chromium values equal to or greater than the highest value found in the present study.

The background levels for copper in sediments varies between 15.1-143.0 mg/kg. Frye (1973) has indicated background levels in Lake Michigan are 30 mg/kg and German (1972) had indicated background levels for copper of 150 mg/kg in the Thunder Bay District of Ontario. Mathers et al (1981) found a range of sediment copper values from 11-64 mg/kg.

The iron content ranges between 21,900 mg/kg and 68,600 mg/kg. The abundance of such minerals as freibergite, siderite and pyrite which contain iron indicates that such values are not unexpected.

Lead occurs at concentrations from a low of 21.6 mg/kg at Station 1 to a high of 1,199 mg/kg at Station2. Frye (1973) suggests background levels of 15-30 mg/kg in bottom sediments as natural in Lake Michigan while Shimp et al (1971) indicate levels of 25-133 mg/kg as being natural background levels for the same area. Mathers et al (1981) identify a range of 11-125 mg/kg for lead in sediments of seven Yukon streams. The high levels such as found at Stations 2, 3, 6 and 7 in the present study is not unexpected in areas where deposits of galena, a lead sulphides, exist in large quantities. Because of the high natural lead levels in the sediments of lower Cache Creek any additional input that is subject to oxidation may increase metal content in the waters which would be of concern from a water quality perspective.

4.3 Bottom Fauna

At the seven stations sampled a total of 227 orgamisms, comprising 38 taxa, were collected from all samples. The densities calcualted from a mean of 3 samples for each station show a wide range of values. The highest density of organisms was found at station 1 (269 individuals/m^2) while the lowest was at station 2 with no organisms found and station 3 with 57 individuals/m^2. Stations 2 and 3 have groundwater flowing from the mine adit. The average number of individuals for all stations is 116/m^2. This value shows a low number of organisms compared to other environmental studies (Mathers et al, 1981, Godin 1984, Soroka 1984 unpublished data). The differences may be due to the poor benthic habitat where the stations near the mine adits don't receive organic imput either by terrestrial or in situ production. Some of the stations (Stations 2, 3 and 6) where located very close to the adit opening. The sampling procedures may also affect the densities by ineffectively catching the organisms.

The low numbers of individuals affect the calculation of the diversity and evenness indices and the validity of the information given. Hugues 1978 shows how the diversity index can be affected by factors other than pollution. For example, in the present study at

TABLE 2 SUMMARY OF THE IONA SILVER BOTTOM FAUNA INDICES AND DENSITY

STATION NUMBER	NUMBER PER FT^2 (mean of 3 samples)	CALCULATED NUMBER PER M^2
1	25	269
2	0	0
3	5	57
4	--	---
5	10	104
6	9	100
7	13	140
8	13	140

STATION NUMBER	DIVERSITY INDEX H'	EVENNESS J'
1	0.69	0.69
2	0.0	0.0
3	0.88	0.97
4	----	----
5	0.76	0.84
6	0.26	0.43
7	0.75	0.78
8	0.97	0.87

station 3 where we see the lowest density, the diversity is 0.88 and evenness is 0.97 (Table 2) which are both higher than the values at the control station (station 1) located above any mine influence.

Stations 1, 7 and 8, located in riffles area of Cache Creek and Ketza River, were dominated by Cinygmula sp. (Ephemeroptera) which shared dominance at station 5 with Zapada sp. and Alloperla sp. (Plecoptera). Station 6, located on ground water flow from a mine adit was dominated by Pseudodiamesa sp. (Chironomidae).

4.4 Fish

Two different species have been collected for the metal analysis of their muscle tissue: the slimy sculpin (Cottus cognatus) and the arctic grayling (Thymallus arcticus). The grayling (4 individuals) were caught at Station 4 on Ketza River while the sculpins (6 individuals) were caught at Station 7 on Cache Creek. No weights, lengths and age were taken from the fish.

The tissue metal analysis for grayling can be compared with results obtained from another portion of the Pelly River drainage (Archibald, 1981). The present study shows that the following metals were present in concentrations from 2 to 5 times greater: calcium (5), copper (2), manganese (3), phosphorus (2), strontium (5), and zinc (2). There is little reference material available to relate these results to. Because the Arctic grayling spends only the summer months in small streams' unless over-wintering habitat is available, and retreats to major rivers to over-winter, it is not possible to determine a reltationship between metal levels in tissues and those levels in water.

If the tissue metal concentration of the two species is compared on a dry weight basis the grayling typically has a lower or equal concentrations for most metals. Exceptions are that potassium and manganese levels are at least twice as high in arctic grayling. For most metals the slimy sculpin contains levels several times higher than grayling as follows:

Aluminum (20x)	Iron (22x)	Sodium (1.5x)
Barium (2x)	Lead (7x)	Strontium (1.5x)
Cadmium (3x)	Manganese (6x)	Titanium (4.5x)
Copper (1.5x)	Silica (8.5x)	Zinc (2x)

A tissue analysis done on the prickly sculpin (Cottus asper) (Reid, McGreer 1981), living in an aquatic system receiving the waste of tailings ponds of a large copper-lead-zinc mine, shows a range of metal concentrations lower than what was found in our analysis. The cadmium range from .05 to .09 ug/g, copper 1.0-3.0 ug/g, lead 1.0-2.0 ug/g and zinc 40-90 ug/g for five different stations. Those values are considered to be in the range of tissue levels reported in the literature (Reid, McGreer 1981). Compared to this data, the metal levels in the present study are higher for cadmium (6x), copper (3x), lead (2x) and zinc (2x). For copper, it has been found that the small fish accumulated more copper per unit of body weight (Anderson and Spear 1980). It is probable that this may apply to the other heavy metals as well, since the metabolism of a smaller individual is greater thus the bioaccumulation is favoured.

REFERENCES

Anonymous, Guidelines for Establishing Water Quality Objective for the Territorial Waters of the Yukon and Northwest Territories. Report of the Working Group on Water Quality Objective to the Chairman, Water Boards, Yukon and Northwest Territories, July (1977).

Anderson P.D. and P.A. Spear. Copper Pharmacokinetics in Fish Gills II, Body Size and Relationship for Accumulation and Tolerance, Water Res. 14(8), 1108-1111, (1980).

APHA, AWWA, WPCF, Standard Methods for the Examination of Water and Wastewater. 15th Ed., 1134 p. (1980).

Archibald, P.L., Burns, B.E., A Baseline Survey of the Water Quality and Conditions in the Streams of the Howard's Pass Area, Yukon Territory. Environmental Protection Service, Yukon Branch, Pacific Region No. 81-13, 63 p., January (1981).

Berube, Y.R. Gilbert, M. Frechette, P. Larochelle, I. Pantu, Mine Waste Contaminant and Water Quality in a Northern Environment. Department of Indian and Northern Affairs, ALUR 1971-72, 184 p., (1972).

California State Water Resources Control Board, Water Quality Criteria. Publication No. 3-A, Second Edition by McKee & Wolf (1963).

Department of Environment, Department of Fisheries and Oceans, Laboratory Manual. Environmental Protection Service, Fisheries and Marine Service, 592 p., (1979).

Department of Indian Affairs and Northern Development (DIAND), Yukon Geology and Exploration 1979-80. Geology section, Whitehorse (1981).

Environmental Protection Service, (EPA), Committee on Water Quality Criteria, Water Quality Criteria 1972, U.S., 594p. (1972).

Environment Canada, Environmental Protection Service, Pollution Sampling Handbook. Fisheries and Marine Service and Environmental Protection Service Laboratory Services, Vancouver, B.C., 121 p. (1976).

Falk, M.R., M.D. Miller and S.J.M. Kostiuk, Biological Effects of Mining Wastes in the Northwest Territories. Environment Canada. Fisheries and Marine Service. Resource Management Branch, Central Region, Technical Report Series No. CENK-73-10, 89p. (1973).

Frye, J.C. and N.F. Shimp. Major, minor and trace elements in sediments of late pleistocene lake saline compared with those in Lake Michigan sediments. Ill St. Geol. Survey - Env. Geo. Notes. 60:14pp. (1973).

German, M.J., Effects of Acid Mine Wastes on the Chemistry and Ecology of Lakes in the Manitowadge Chain District of Tunder Bay. Ontario Water Resources Commission. 19pp., (1972).

Hamence, J.H. The composition of muds from rivers, estuaries and lakes. J. Aso. Publ. Anal. 5(3), 88-100 (1967).

Health and Welfare Canada, Guidelines for Drinking Water Quality 1978, Supply and Services, Canada. (1979).

Hicks, H.B., Report on Properties of Iona Silver Mines Ltd. Ketza River Area, Yukon Territory. Brodie Hicks Engineering Ltd., Vancouver, B.C. 17p., (1979).

Hugues, B.D., The influence of factors other than pollution on the value of Shannon's diversity index for benthic macro-invertebrates in streams, Water Research. (12) 359-364, (1978).

Inland Waters Directorate, Guidelines for Surface Water Quality. Vol. 1, Inorganic Chemical Substances. Environment Canada, Ottawa (1979,1980).

Low, C.J. Personal communication. Invertebrate Biologist Consultant, 33 Milton Street, Nanaimo, B.C.

Mathers, J.S, N.O. West and B. Burns, "Aquatic and Wildlife resources of seven Yukon streams subject to placer mining", Department of Fisheries and Oceans Canada, (1981).

Merritt, R.W. and K.W. Commins, An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing Company, Dubuque, U.S.A. 441p., (1978).

Ontario Ministry of the Environment, Water Management Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, (1978).

Oswald, E.T. and J.P. Senyk, Ecoregions of Yukon Territory. Fisheries and Environment Canada, 115p., (1977).

Pennak, R.W., Freshwater Invertebrates of the United States. John Wiley and Son, New York, 803p., (1978).

Philipchuk, M.F. and V.F. Sevast'yanov, Arsenic from recent sediments of the Black Sea. Do. Kl. Akad. Nauk. SSR, 179(3):697-700 (1968).

Pielou, E.C., Ecological Diversity. John Wiley and Son. Toronto (1975).

Reid, B.J. and E.R. McGreer, Bioaccumulation of Heavy Metals by Sculpin (Cottus asper) exposed to mine Tailings. In Proceedings of the Eight Annual Aquatic Toxicity Workshop Nov. 2-4, 1981, Guelph, Ontario. Canadian Technical Report of Fisheries and Aquatic Sciences, No. 1151 (1983).

Sadlier-Brown, T.L. and A.E. Nevin, A Report on the Ketza River Property of Iona Silver Mines Ltd. Watson Lake Mining Division Yukon. Nevin, Sadlier-Brown, Goodbrand Ltd. Consulting Geologist, Vancouver, B.C. 25p., (1978).

Shimp, N.F., J.A. Schleicher, R.R. Ruch and H.V. Leland. Trace elements and organic carbon accumulation in the most recent sediments of southern Lake Michigan. Env. Geo. Nates Ill St. Geo. Survey. No 41, 25p., (1971).

Thurston, R.V., R.C. Russo, C.M. Fetteroff Jr., T.A. Edsall and Y.M. Barber Jr. (Eds.), A Review of the EPA Red Book; Quality Criteria for Water. Water Quality Section, Amercian Fisheries Society, Bethesda MD. 313p., (1979).

Wetzel, R.G., Limnology. Saunders College Publ. Philadelphia, 743p., (1975).

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APPENDICES

APPENDIX I

COLLECTION, PRESERVATION, ANALYSIS OR IDENTIFICATION METHODS AND WATER QUALITY CRITERIA

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Temperature		In situ temperature reading.	Standard Centigrade Thermometer	
Flow		Flow measurements taken for general evaluation purposes only.	Cross-section of stream was estimated and the velocity of flow was measured by noting the time it took a twig to travel a given length of the stream, i.e., 5 m. Flow measurement given in m^3/s.	
Dissolved Oxygen	1.00 mg/L	Duplicate samples collected in 300 mL glass BOD bottles. The BOD bottles were rinsed 3 times with sample before filling. Preserved with 2 mL manganese sulphate and 2 mL alkali-iodide-azide solution and shaken 15 times. A water seal was maintained and DO analysis was done within 7 days.	Iodometric Azide Modification Winkler Titration Method	048
pH		Small aliquots of sample were taken and read soon after collection. No preservative.	Potentiometric	080
Conductivity	0.2 umhos/cm	In situ measurement. Laboratory measurement. No preservative. The measurement was taken from the same as NH_3 below.	YSI Conductivity Meter Model 33 Radiometer Conductivity Meter (CDMC) with radiometer conductivity cell.	044

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Ammonia NH_3-N	0.005 mg/L	Single grab samples collected in 2 litre linear polyethylene containers. The container was rinsed 3 times with sample before it was filled. No preservatives. Stored at 4°C.	Phenol Hypochlorite-Colorimetric-Automated	058
Colour	5 (colour units)	Same sample as NH_3.	Platinum-Cobalt Visual Comparison	040
Turbidity	1.0 (FTU)	Same sample as NH_3.	Nephelometric Turbidity	130
Non-Filterable Residue (NFR)	5.0 mg/L	Same sample as NH_3.	Filtration, drying and weighing of residue on filter	104
Filterable Residue (FR)	10.0 mg/L	Same sample as NH_3.	Filtration, drying and weighing of filtrate	100
Total Alkalinity	1.0 mg/L as $CaCO_3$	Same sample as NH_3.	Potentiometric Titration	006
Total Phosphate T PO_4-P	0.005 mg/L	Same sample as NH_3.	Acid-persulphate, Autoclave Digestion	086

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Nitrite NO_2-N	0.005 mg/L	Same sample as NH_3.	Diazotization-Colorimetric-Automated	070
Nitrate NO_3-N	0.01 mg/L	Same sample as NH_3.	Cadmium Copper Reduction Colorimetric Automated	072
Sulphate SO_4	1.0 mg/L	Same sample as NH_3.	*Barium Chloranilate* -UV Spectrophotometric	122
Chloride Cl	0.5 mg/L	Same sample as NH_3.	Thiocyanate-Combined Reagent-Colorimetric	024
Cyanide CN	0.03 mg/L	Sample was collected in a 1 litre Nalgene wide mouth bottle, which was rinsed 3 times with sample before filling. The sample was preserved with NaOH pellets to pH >12 and stored at 4°C.	Tetracyanonickelate (II) - UV - Colorimetric	032
Silica Total Si	0.5 mg/L	Same sample as NH_3.	Ascorbic Acid Reduction - Colorimetric	118
Mercury Total Hg	0.0002 mg/L	Single samples were collected in a 200 mL linear polyethylene bottle. Preserved with a 10 mL 5% nitric dichromate solution.	Open *Flameless* System *for* Hg-AAS Determination	211 224 284 411

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
Extractable Metals	mg/L	Single samples collected in 200 mL linear polyethylene bottles. The bottle was rinsed 3 times with sample before filling. Preserved to a pH <1.5 using 2.0 mL concentrated HNO_3.	Inductively Coupled Argon Plasma (ICAP) combined with Optical Emission Spectrometer (OES)	210 592
Al	0.05			
As	0.075			
Ba	0.0015			
Be	0.001			
Ca	0.05			
Cd	0.004			
Co	0.008			
Cr	0.008			
Cu	0.005			
Fe	0.005			
Mg	0.10			
Mn	0.001			
Mo	0.015			
Na	0.5			
Ni	0.04			
Pb	0.04			
Sb	0.04			
Se	0.08			
Sn	0.10			
Sr	0.002			
Tl	0.004			
V	0.02			
Zn	0.005			

APPENDIX I TABLE 1 WATER SAMPLE COLLECTION, PRESERVATION AND ANALYSIS METHODS (continued)

PARAMETER	DETECTION LIMIT	COLLECTION AND PRESERVATION PROCEDURE[1]	ANALYTICAL PROCEDURE	METHOD SECTION[2]
As	0.0005 mg/L	Same sample as metals.	Hydride Generation - ICAP	J. Davidson EPS Lab.
Cd	0.001 mg/L	Same sample as metals.	Graphite Atomic Absorption Flameless Technique (AAS)	Atomic Absorption Jerrel-Ash 850 Manual
Cu	0.001 mg/L	Same sample as metals.		
Pb	0.001 mg/L	Same sample as metals.		
Zn	0.001 mg/L	Same sample as metals.		
Ag	0.03 mg/L	Same sample as metals.	Flame Atomic Absorption Spectrophotometry	210 290
K	0.01 mg/L	Same sample as metals.	Flame Atomic Emission Spectrophotometry	210 423
Total Hardness	0.030 mg/L as $CaCO_3$	Same sample as metals.	The sum of the ICAP results for Mg x 4.116 and Ca x 2.497 reported as mg/L $CaCO_3$	

1 As described in *Environment Canada* (1976).

2 As described in Department of Environment (1979).

APPENDIX I TABLE 2 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS

PARAMETER	COLLECTION/PREPARATION	ANALYSIS	METHOD CODE[1]
All Samples	Creek and River Stations: Sediment samples were collected using an aluminum shovel to scoop sample into pre-labelled Whirl-Pak bags. Three samples were taken at each station. Samples were kept cool and were frozen (-4°C) as soon as possible.		
Cyanide CN	Some distilled water was added to a known weight of sediment sample before starting the digestion step in the analytical procedure.	Tetracyanonickelate (II) - UV - Colorimetric Method	032
Mercury Hg (Total)	Sample was freeze-dried for 48 hours to remove water. Sample was sieved through a size 100 mesh (.15 mm) stainless steel sieve. The portion passing through was analyzed for mercury. Sample was completely oxidized by digestion with H_2SO_4 and H_2O_2.	Atomic Absorption Spectrophotometer - Open Flameless System	231 236 238 275 284 411
Metals (Leachable) Al Ba Be Ca Cd Cr Cu	Same as Mercury except portion passing through was analyzed for metals. Sample was leached with Hcl and HNO_3. The sample was heated for 3 hours.	Inductively Coupled Argon Plasma (ICAP) Combined with Optical Emission Spectrometer (OES)	231 236 238 242

APPENDIX I TABLE 2 SEDIMENT COLLECTION, PREPARATION AND ANALYSIS METHODS (continued)

PARAMETER	PREPARATION	ANALYSIS	METHOD CODE[1]
Metals (Leachable) (continued)			
Fe			
Mg			
Mn			
Mo			
Na			
Ni			
P			
Pb			
Si			
Sn			
Sr			
Ti			
V			
Zn			
As	Same as other metals.	Hydride Generation ICAP	J. Davidson
[2]Sb	Same as other metals.	Hydride Generation ICAP	EPS Lab
[2]Se	Same as other metals.	Hydride Generation ICAP	
Ag	Same as other metals.	Flame Atomic Absorption Spectrophotometry	290
Cd	Same as other metals.	Graphite Flameless Atomic Absorption	Jerrel-Ash 850 Manual
K	Same as other metals.	Flame Atomic Emission Spectrophotometry	423
Particle Size	Sample was freeze-dried.	Standard Sieving Operation	078

1 Department of Environment, Department of Fisheries and Oceans, Laboratory Manual, Environmental Protection Service, Fisheries and Marine Service (1979).

2 The concentrations of Sb and Se are for information only since the analysis method has not yet been fully tested.

APPENDIX I TABLE 3 BOTTOM FAUNA COLLECTION, PRESERVATION AND IDENTIFICATION METHODS

FIELD COLLECTION, SAMPLING PROCEDURES AND PRESERVATION	LABORATORY PROCEDURES	IDENTIFICATION AND ENUMERATION
Surber Sampler: Creek and river samples were taken using a Surber Sampler with a 60 cm long net (mesh size 0.76 mm). Area sampled was 900 cm^2 (1 ft^2). Surber samples were washed into a cup at the bottom of a plankton net (.75 mm mesh size), put in separate labelled glass jars and preserved with 10% formalin. 3 samples were taken at each station.	Bottom fauna was removed from other material in a labelled vial containing 70% methanol.	Bottom fauna was sent to Dr. C. Low, Consulting Invertebrate Biologist, Nanaimo, B. C. for identification to genus, species if possible, and enumeration.

APPENDIX I TABLE 4 WATER QUALITY CRITERIA FOR DRINKING WATER AND AQUATIC LIFE

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)
Physical				
Colour Pt. Counts	15	1		
Odour and taste	0	1		
Turbidity J.T.U.	5	1		
Chemical				
Alkalinity mg/L (Total)	Not considered a public health problem	4	>20	3
Aluminum (Al) mg/L	Not considered a public health problem	7	0.1	5
Ammonia (NH_3-N) mg/L	0.5	4	0.02	3
Antimony (Sb) mg/L				
Arsenic (As) mg/L	0.05	1	0.05	2
Barium (Ba) mg/L	1.0	1	5.0	7
Boron (Bo) mg/L	1.0	1		
Cadmium (Cd) mg/L	0.005	1	0.0002	2
Calcium (Ca) mg/L	75-200	7		
Chloride (Cl)mg/L	250	1		
Chromium (Cr) mg/L	0.05	1	0.04	2
Cobalt (Co) mg/L				
Conductivity @ 25°C (umhos/cm)	Depends on dissolved salts	7	150-500	6
Copper (Cu) mg/L	1.0	1	0.005	5
Cyanide (CN) mg/L	0.2	1	0.005	3
Dissolved oxygen (% saturation)	Near 100%	4	$\geq$5.0 mg/L	3

APPENDIX I TABLE 4 WATER QUALITY CRITERIA FOR DRINKING WATER AND AQUATIC LIFE (continued)

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)
Fluoride (F) mg/L	1.5	1	1.5	7
Hardness (Total) as mg/L $CaCO_3$	80-100	1		
Iron (Fe) mg/L	0.3	1	1.0	3
Lead (Pb) mg/L	0.05	1	0.005 (soft H_2O*) 0.01 (hard H_2O*)	2 2
Magnesium (Mg) mg/L	50	4		
Manganese (Mn) mg/L	0.05	1	1.0	7
Mercury (Hg) mg/L	0.002	1	0.0001-0.0002	2
Molybdenum (Mo)				
Nickel (Ni) mg/L	0.25	2	0.025 (soft H_2O*) 0.25 (hard H_2O*)	2 2
Nitrate (NO_3-N) mg/L	10	1		
Nitrite (NO_2-N) mg/L	0.001	1		
pH units	6.5 - 8.5	1	6.5 - 9.0	3
Phosphorus (P) mg/L (Total)			0.020 to prevent algae	5
Potassium (K) mg/L				
Residue: Filterable mg/L (Total dissolved solids)	1000	4	70 - 400 with a maximum of 2000	6
Residue: Non-Filterable (mg/L)				
Selenium (Se) mg/L	0.01	1	0.01	2
Silica (Si) mg/L				
Silver (Ag) mg/L	0.05	1	0.0001	2
Sodium (Na) mg/L	20	1		
Strontium (Sr) mg/L	10	1		
Sulphate (SO_4) mg/L	500	1		
Tin (Sn) mg/L	Not present in natural waters	7		
Titanium (Ti) mg/L				

APPENDIX I TABLE 4 WATER QUALITY CRITERIA FOR DRINKING WATER AND AQUATIC LIFE (continued)

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)
Total Inorganic Carbon (TIC)				
Total Organic Carbon (TOC)	5.0	5		
Vanadium (V)				
Zinc (Zn) mg/L	5.0	1	0.030	5

* Soft water has a total hardness less than 95 mg/L as $CaCO_3$. Hard water has a total hardness of more than 95 mg/L as $CaCO_3$ (Reference 6).

REFERENCES:

1. Health & Welfare Canada, Guidelines for Canadian Drinking Water Quality 1978, Supply and Services, Canada (1979).

2. Inland Waters Directorate, Guidelines for Surface Water Quality, Vol. 1, Inorganic Chemical Substances. Environment Canada, Ottawa (1979, 1980).

3. Thurston, R.V., R.C. Russo, C.M. Fetteroff Jr., T.A. Edsall, and Y.M. Barber Jr. (Eds.), A Review of the EPA Red Book: Quality Criteria for Water. Water Quality Section, American Fisheries Society, Bethesda, MD, 313p. (1979).

4. Anonymous, Guidelines for Establishing Water Quality Objectives for the Territorial Waters of the Yukon and Northwest Territories. Report of the Working Group on Water Quality Objectives to the Chairmen, Water Boards, Yukon and Northwest Territories, July (1977).

5. Ontario Ministry of the Environment, Water Management - Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment. (1978).

APPENDIX I TABLE 4 WATER QUALITY CRITERIA FOR DRINKING WATER AND AQUATIC LIFE (continued)

SUBSTANCE	RECOMMENDED LEVEL(S) FOR DRINKING WATER	REFERENCE(S)	RECOMMENDED LEVEL(S) FOR AQUATIC LIFE	REFERENCE(S)

6. Environment Canada, Pollution Sampling Handbook. Pacific Region Laboratory Services, Fisheries Operations and Environmental Protection Service, West Vancouver, B.C. (1976).

7. California State Water Resources Control Board, Water Quality Criteria. Publication No. 3-A Second Edition by McKee and Wolf. (1963).

APPENDIX II

WATER QUALITY DATA

APPENDIX II IONA SILVER WATER QUALITY DATA - JULY 30, 1981

STATION NUMBER	FLOW m^3/s	TEMP (°C)	D.O. (mg/L)	% D.O. SATURATION (%)	IN SITU pH	LAB pH	IN SITU CONDUCTIVITY (umhos/cm)	LAB CONDUCTIVITY (umhos/cm) at 25°C	COLOUR (colour units)	TURBIDITY (FTU)
1	0.24 (e)	11	8.38	87	8.20	8.4	236	360	<5	<1
2	0.0026 (e)	2	9.93	87	8.10	8.2	550	930	<5	1.9
3	0.0013 (e)	4	8.78	78	7.90	8.3	438	830	<5	<1
5	0.84 (e)	9	9.08	91	8.41	8.4	232	365	<5	<1
6	0.0008 (e)	4	9.43	87	8.10	8.3	340	615	5	<1
7	1.39 (e)	10	8.80	89	8.45	8.4	259	389	<5	<1
8	2.51 (e)	11	8.53	87	8.30	8.4	279	410	5	<1

(e) Very rough estimate.

APPENDIX II IONA SILVER WATER QUALITY DATA - JULY 30, 1981 (continued)

STATION NUMBER	N.F. RESIDUE (mg/L)	F. RESIDUE (mg/L)	TOTAL ALKALINITY (mg/L as $CaCO_3$)	TOTAL HARDNESS (mg/L as $CaCO_3$)	TOTAL PO_4-P (mg/L)	NO_2-N (mg/L)	NO_3-N (mg/L)	NH_3-N (mg/L)	SO_4 (mg/L)	CN (mg/L)	Cl (mg/L)
1	<5	213	187	182	<0.005	<0.005	<0.01	<0.005	30.9	<0.03	<0.5
2	<5	712	310	551	<0.005	<0.005	0.03	0.031	238	<0.03	0.8
3	<5	542	375	436	<0.005	0.015	0.05	0.089	115	<0.03	1.4
5	<5	223	124	174	<0.005	<0.005	0.01	<0.005	60.8	<0.03	<0.5
6	<5	438	164	324	<0.005	<0.005	0.03	<0.005	162	<0.03	0.5
7	<5	245	124	184	<0.005	<0.005	0.02	<0.005	68.8	<0.03	<0.5
8	<5	251	155	202	<0.005	<0.005	0.04	<0.005	56.1	<0.03	0.5

APPENDIX II IONA SILVER WATER QUALITY DATA - JULY 30, 1981 (continued)

STATION NUMBER	Ag mg/L	Al mg/L	As mg/L	Ba mg/L	Be mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Hg mg/L	K mg/L
1	<0.03	<0.05	<0.0005	0.144	<0.001	49.2	<0.001	<0.008	<0.008	0.006	0.026	<0.0002	0.43
2	<0.03	<0.05	0.0009	0.0119	<0.001	112	<0.001	<0.008	<0.008	0.004	0.084	<0.0002	0.87
3	<0.03	<0.05	0.0249	0.0298	<0.001	63.4	<0.001	<0.008	<0.008	0.010	0.119	<0.0002	5.52
5	<0.03	<0.05	0.0101	0.0088	<0.001	49.1	<0.001	<0.008	<0.008	0.004	0.047	<0.0002	0.21
6	<0.03	0.11	0.0104	0.0188	<0.001	69.6	<0.001	<0.008	<0.008	0.006	0.681	<0.0002	0.39
7	<0.03	0.08	0.0097	0.0164	<0.001	46.8	<0.001	<0.008	<0.008	0.006	0.038	<0.0002	0.27
8	<0.03	<0.05	<0.0043	0.0515	<0.001	49.8	<0.001	<0.008	<0.008	0.005	0.053	<0.0002	0.39

APPENDIX II   IONA SILVER WATER QUALITY DATA - JULY 30, 1981 (continued)

STATION NUMBER	Mg mg/L	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	Pb mg/L	Sb mg/L	Se mg/L	Si mg/L	Sn mg/L	Sr mg/L	Ti mg/L	V mg/L	Zn mg/L
1	14.4	0.002	<0.015	1.0	<0.04	<0.001	<0.04	<0.08	2.4	<0.10	0.167	<0.004	<0.02	0.018
2	66.0	0.052	<0.015	<0.5	<0.04	<0.001	<0.04	<0.08	1.9	<0.10	0.817	<0.004	<0.02	0.019
3	67.5	0.063	<0.015	11.0	<0.04	0.008	0.13	<0.08	3.1	<0.10	1.59	<0.004	<0.02	0.033
5	12.6	0.003	<0.015	0.6	<0.04	<0.001	<0.04	<0.08	2.2	<0.10	0.130	<0.004	<0.02	0.022
6	36.6	0.189	<0.015	<0.5	<0.04	0.025	0.13	<0.08	2.1	<0.10	0.161	<0.004	<0.02	0.059
7	16.2	0.004	<0.015	0.7	<0.04	<0.001	<0.04	<0.08	2.3	<0.10	0.155	<0.004	<0.02	0.022
8	18.9	0.003	<0.015	1.0	<0.04	<0.001	<0.04	<0.08	2.4	<0.10	0.190	<0.004	<0.02	0.017

APPENDIX III

SEDIMENT DATA

APPENDIX III TABLE 1 IONA SILVER SEDIMENT PARTICLE SIZE ANALYSIS - JULY 30, 1981

STATION NUMBER	PERCENT COMPOSITION				
	>500 um	250-500 um	150-250 um	63-150 um	<63 um
1-1	46.4	27.4	11.9	6.5	7.8
1-2	82.6	0	10.1	3.4	3.9
1-3	37.8	48.9	8.9	2.3	2.0
2-1	62.0	7.5	5.0	8.7	16.8
2-2	72.4	8.4	4.6	7.7	6.9
2-3	69.8	7.9	4.6	6.6	11.1
3-1	67.5	10.9	3.8	4.7	13.1
3-2	61.9	6.3	4.0	7.0	20.8
3-3	51.0	9.9	5.8	12.8	20.5
5-1	89.2	6.7	1.5	0.8	1.8
5-2	85.8	8.5	2.3	2.0	1.4
5-3	88.6	7.5	1.6	1.0	1.3
6-1	41.9	6.5	5.5	25.0	21.1
6-2	35.7	8.8	9.3	21.7	24.5
6-3	39.1	11.5	9.7	21.9	17.8
7-1	89.5	6.0	1.8	1.8	0.9
7-2	86.1	10.1	2.1	1.1	0.6
7-3	83.1	10.0	4.0	2.2	0.7
8-1	64.6	17.1	9.0	7.0	2.3
8-2	59.3	29.0	8.0	3.3	0.4
8-3	61.8	22.0	10.0	3.9	2.3

APPENDIX III TABLE 2 IONA SILVER SEDIMENT CHEMISTRY DATA - JULY 30, 1981
(all measurements are in mg/kg dry weight unless otherwise noted)

STATION	CN w/w*	Ag	Al	As	Ba	Be	Ca	Cd	Cr	Cu	Fe	Hg	K	Mg
1-1	<0.20	<4.94	16200	11	800.0	0.593	36400	0.634	56.9	29.8	30900	<0.196	3630	24900
1-2		<4.90	15900	11	1200	0.595	37500	0.801	57.2	29.1	31500	<0.185	3560	24700
1-3		<4.88	17900	12	1270	0.651	42200	0.683	64.9	30.8	33900	<0.167	4610	27600
2-1	<0.15	18.2	4530	59	324.0	0.526	41600	<0.57	9.38	86.5	68600	0.159	1070	7480
2-2		<4.83	4600	19	57.6	0.611	40400	<0.57	9.41	18.4	38000	<0.125	983	3530
2-3		6.66	4190	11	92.5	0.641	56500	<0.57	9.0	25.4	39600	<0.130	979	5420
3-1	<0.13	12.8	10900	842	136.0	0.523	61400	1.15	55.6	143.0	49800	0.157	1370	9480
3-2		11.9	7070	294	80.3	0.443	72700	1.07	31.2	108.0	41900	<0.125	895	6040
3-3		12.7	11200	553	139.0	0.542	52800	0.793	62.1	115.0	49400	0.150	1210	10400
5-1	<0.19	<4.95	8370	182	46.9	0.388	75400	1.10	16.6	43.9	38500	<0.196	680	11100
5-2		<4.84	8150	303	54.0	0.357	72800	0.732	15.0	39.1	37800	<0.185	710	11100
5-3		<4.96	8710	260	49.0	0.364	75600	1.10	20.4	41.6	38000	<0.196	728	11600
6-1	<0.20	<4.88	3470	55	216.0	0.415	120000	0.882	11.0	28.1	28600	<0.313	795	59300
6-2		<4.79	2360	21	90.8	0.279	153000	1.23	8.07	15.1	21900	<0.130	458	84300
6-3		<4.97	3440	67	278.0	0.405	101000	1.16	10.7	32.0	29700	<0.294	846	51700
7-1	<0.16	<4.93	7530	214	192.0	0.362	72500	0.805	17.7	43.1	42000	0.195	707	19200
7-2		<4.93	7720	131	358.0	0.337	78000	0.980	27.0	52.3	46600	<0.185	726	24900
7-3		<4.93	7040	211	209.0	0.361	70700	<0.58	15.5	44.6	41100	<0.189	560	20500
8-1	<0.19	<4.86	10400	123	179.0	0.420	62200	0.793	34.1	30.0	37100	<0.133	1030	20300
8-2		<4.87	10500	119	193.0	0.366	60200	<0.57	36.4	26.6	35800	<0.132	988	20700
8-3		<4.98	9930	123	122.0	0.399	58200	0.814	33.8	28.3	35800	<0.127	913	18600

w/w* Means wet weight. All other concentrations in this table are given in dry weight for the portion passing a 150 um sieve.

APPENDIX III TABLE 2 IONA SILVER SEDIMENT CHEMISTRY DATA - JULY 30, 1981 (continued)
(all measurements given in mg/kg dry weight unless otherwise noted)

STATION	Mn	Mo	Na	Ni	P	Pb	Si	Sn	Sr	Ti	V	Zn
1-1	365.0	2.80	145.0	41.7	1100	20.8	5120	<16.4	56.9	617.0	66.4	169.0
1-2	433.0	<2.44	170.0	41.7	1100	19.8	5720	<16.3	61.4	618.0	64.4	168.0
1-3	503.0	<2.44	175.0	50.6	1180	24.3	5220	<16.3	68.8	685.0	74.5	177.0
2-1	2410	2.40	139.0	20.7	433.0	2640	4160	<16.0	125.0	15.1	3.27	70.9
2-2	1390	<2.42	111.0	29.6	574.0	494.0	3790	<16.1	100.0	16.2	5.46	51.8
2-3	1470	<2.44	135.0	31.5	359.0	463.0	4020	<16.3	130.0	18.4	4.07	54.3
3-1	1530	<2.45	202.0	48.6	1060	1010	4220	<16.4	214.0	279.0	42.6	239.0
3-2	1280	<2.42	165.0	35.7	878.0	658.0	3620	<16.2	231.0	180.0	23.3	209.0
3-3	1470	2.67	190.0	51.9	1100	856.0	3720	<16.2	189.0	277.0	47.0	232.0
5-1	806.0	<2.47	144.0	33.6	601.0	31.0	4090	<16.5	146.0	23.9	6.93	211.0
5-2	839.0	<2.43	128.0	32.9	600.0	45.7	4350	<16.2	142.0	28.0	7.36	194.0
5-3	874.0	<2.89	150.0	35.9	629.0	32.4	4560	<16.5	150.0	29.3	7.69	208.0
6-1	1380	6.92	236.0	45.9	681.0	487.0	3240	<16.3	119.0	32.6	36.4	216.0
6-2	1290	2.55	249.0	19.1	636.0	407.0	2450	<16.0	119.0	32.5	14.6	159.0
6-3	1350	7.85	161.0	47.6	640.0	542.0	3400	<16.6	105.0	29.5	40.1	238.0
7-1	1410	5.10	172.0	44.8	940.0	364.0	3770	<16.4	143.0	39.5	20.7	172.0
7-2	1590	5.02	140.0	48.9	1210	606.0	3710	<16.4	157.0	47.3	23.8	164.0
7-3	1520	3.20	141.0	42.0	1040	286.0	3580	<16.4	140.0	38.8	19.3	168.0
8-1	866.0	<2.76	147.0	41.5	1130	85.5	3790	<16.2	133.0	297.0	29.6	148.0
8-2	817.0	<2.44	134.0	38.1	1180	80.0	3650	<16.3	132.0	329.0	28.6	136.0
8-3	838.0	<2.49	116.0	39.9	1040	81.5	3520	<16.6	130.0	258.0	26.8	145.0

APPENDIX IV

BOTTOM FAUNA DATA

APPENDIX IV TABLE 1 BOTTOM FAUNA TAXONOMIC GROUPS FOUND IN THE IONA SILVER WATERSHED (Numbers 1, 2, 3 etc. are cross referenced to data in Table 2 of Appendix IV)

	Phylum:	Annelida
	Class:	Oligochaeta
	Order:	Haplotaxia
1.	Family:	Enchytraeidae
	Phylum:	Arthropoda
	Class:	Insecta
	Order:	Plecoptera
	Family:	Nemouridae
2.		_Zapada_ sp.
	Family:	Capniidae
3.		_Capnia_ sp.
	Family:	Perlodidae
4.		_Arcynopteryx_ sp.
	Family:	Chloroperlidae
5.		_Alloperla_ sp.
6.	Order:	Ephemeroptera adult
	Family:	Heptageniidae
7.		_Cinygmula_ sp.
8.		_Epeorus_ sp.
	Family:	Siphlonuridae
9.		_Ameletus_ sp.
	Family:	Baetidae
10.		_Baetis_ sp.
	Family:	Ephemerellidae
11.		_Ephemerella_ _doddsi_ (moult)
	Order:	Trichoptera
	Family:	Hydropsychidae
12.		_Arctopsyche_ sp.
	Family:	Glossomatidae
13.		_Agapetus_ sp.
	Family:	Rhyacophiloidae

* Numbers correspond to actual individuals identified and listed in Appendix IV, Table 2.

APPENDIX IV TABLE 1 BOTTOM FAUNA TAXONOMIC GROUPS FOUND IN THE IONA SILVER WATERSHED (continued) (Numbers 1, 2, 3 etc. are cross referenced to data in Table 2 of Appendix IV)

14.		_Rhyacophila tucula_
15.	Family:	Limnephiloidae (undet. juv.)
16.	Order:	Lepidoptera (larva)
17.	Order:	Diptera (undet. damaged)
18.	Family:	Tipulidae
19.		_Erioptera_ sp.
20.		_Pseudolimnophila_ sp.
21.		_Tipula_ sp.
	Family:	Simuliidae
22.		_Onychodactylum_ sp. pupa
23.	Family:	Chironomidae pupae
	Subfamily:	Diamesinae
24.		_Pseudodiamesa_ sp.
25.	Subfamily:	Orthocladiinae
26.		_Brillia_ sp.
27.		_Cardiocladius_ sp.
28.		_Cricotopus_ sp.
29.		_Heterotrissocladius_ sp.
30.		_Orthocladius_ sp.
31.		_Parametriocnemus_ sp.
32.		_Psectrocladius_ sp.
33.		_Trichocladius_ sp.
	Subfamily:	Chironominae
34.		_Xenochironomus_ sp.
	Family:	Empididae
35.		_Clinocera_ sp.
36.		_Hemerodromia_ sp.
37.	Family:	Muscidae (undet. adult)
	Order:	Homoptera
38.	Family:	Aphididae (terr)

APPENDIX IV TABLE 2 IONA SILVER BOTTOM FAUNA DATA - JULY 30, 1981

	TAXONOMIC GROUP	1	2	3	5	6	7	8
1	Enchytraeidae	-	-	-	-	-	1	-
2	Zapada sp.	8	-	-	9	-	4	4
3	Capnia sp.	1	-	-	1	-	-	3
4	Arcynopteryx sp.	-	-	-	-	-	-	1
5	Alloperla sp.	10	-	-	6	-	-	4
6	Ephemeroptera adult	-	-	-	-	-	-	1
7	Cinygmula sp.	40	-	-	7	-	17	9
8	Epeorus sp.	5	-	-	2	-	4	-
9	Ameletus sp.	-	-	-	-	-	-	3
10	Baetis sp.	1	-	-	1	-	2	1
11	Ephemerella doddsi (moult)	1	-	-	-	-	-	-
12	Arctopsyche sp.	-	-	-	2	-	1	-
13	Agapetus sp.	-	-	-	-	-	1	-
14	Rhyacophila tucula	4	-	-	-	-	6	-
15	Limnephilidae (undet. juv.)	-	-	3	-	-	-	-
16	Lepidoptera larva	-	-	-	-	1	-	-
17	Diptera (undet. damaged)	-	-	2	-	-	-	-
18	Tipulidae	-	-	-	-	-	-	-
19	Erioptera sp.	-	-	-	-	-	-	1
20	Pseudolimnophila sp.	-	-	-	-	2	-	-
21	Tipula sp.	-	-	1	-	-	-	-
22	Onychodactylum sp pupa	-	-	-	-	-	-	1
23	Chironomidae pupae	-	-	-	-	2	-	1

APPENDIX IV TABLE 2 IONA SILVER BOTTOM FAUNA DATA - JULY 30, 1981

TAXONOMIC GROUP	1	2	3	5	6	7	8
24 Pseudodiamesa sp.	-	-	-	-	21	-	-
25 Orthocladiinae	-	-	-	-	-	-	-
26 Brillia sp.	-	-	2	-	1	-	1
27 Cardiocladius sp.	1	-	-	-	-	2	3
28 Cricotopus sp.	-	-	1	-	-	-	3
29 Heterotrissocladius sp.	-	-	2	-	-	-	-
30 Orthocladius sp.	-	-	1	-	-	-	-
31 Parametriocnemus sp.	-	-	1	-	-	-	-
32 Psectrocladius sp.	-	-	1	-	-	-	-
33 Trichocladius sp.	-	-	1	-	1	-	-
34 Xenochironomus sp.	1	-	-	-	-	-	-
35 Clinocera sp.	3	-	-	1	-	1	-
36 Hemerodromia sp.	-	-	-	-	-	-	1
37 Muscidae (undet. adult)	-	-	1	-	-	-	-
38 Aphididae (terr.)	-	-	-	-	-	-	1
Column Total	75	0	16	29	28	39	38
Total Number at Genera Level	75	0	10	29	25	38	35
Number of Genera	11	0	8	8	4	9	13
Diversity (H')	.69	0	.88	.76	.26	.75	.97
Evenness (J')	.66	0	.97	.84	.43	.78	.87

APPENDIX V

FISH TISSUE METAL CONCENTRATIONS

APPENDIX V FISH TISSUE METAL CONCENTRATIONS IN ARCTIC GRAYLING (*Thymallus arcticus*)

FROM STATION 4 IONA SILVER - JULY 30, 1981 (results in mg/kg)

	Ag	Al	As	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K
Wet Concentration	<0.310	1.03	<1.55	0.845	<0.0103	6490	0.0392	<0.155	0.337	1.49	7.18	0.044	5120
Dry Concentration	<1.40	4.66	<6.99	3.81	<0.0466	29300	0.177	<0.699	1.52	6.71	32.3	0.1979	23100

	Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Si	Sn	Sr	Tl	V	Zn
Wet Concentration	330.0	1.55	<0.31	656.0	<0.827	5560	0.153	<0.827	2.69	<2.07	5.6	<0.0827	<0.414	22.5
Dry Concentration	1490	6.99	<1.4	2950	<3.73	25100	0.690	<3.73	12.1	<9.32	25.3	<0.373	<1.86	102.0

APPENDIX V FISH TISSUE METAL CONCENTRATIONS IN SLIMY SCULPIN (*Cottus cognatus*)

FROM STATION 7 IONA SILVER - JULY 30, 1981 (results in mg/kg)

	Ag	Al	As	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg	K
Wet Concentration	<0.331	22.7	2.32	1.77	<0.011	10500	0.122	<0.165	0.417	2.28	170.0	0.046	3130
Dry Concentration	<1.40	95.9	<9.77	7.45	<0.0465	44100	0.514	<0.698	1.76	9.63	719.0	0.1938	13200

	Mg	Mn	Mo	Na	Ni	P	Pb	Sb	Si	Sn	Sr	Ti	V	Zn
Wet Concentration	319.0	10.5	<0.331	1050	<0.883	6600	1.12	<0.883	24.4	<2.21	8.58	0.389	<0.441	41.3
Dry Concentration	1350	44.4	<1.4	4410	<3.72	27800	4.72	<3.72	103.0	<9.31	36.2	1.64	<1.86	174.0