A Preliminary Environmental Impact Assessment of Abandoned Hard Rock Mines, Yukon Territory

By

Ann P. Duffy and Debbie Mahoney

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ABSTRACT

This report has been prepared by the Environmental Protection Service to discuss and evaluate environmental impact of the Yukon's abandoned hard-rock mines. It is necessary that environmental problems associated with the post-abandonment phase be recognized, so that when planning for future developments, consideration of these post-abandonment environmental problems will occur.

In the past, efforts of regulatory agencies and the mining industry have concentrated on addressing the environmental problems associated with presently operating mine-mill complexes. More recently, development of post-abandonment guidelines and reclamation measures has been given greater consideration since environmental impacts from abandoned mines have the potential to exist for many years.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

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1 INTRODUCTION

Mining activity can be classified into a number of phases which occur in the following chronological order: exploration, development, operation and abandonment which for the purpose of this report includes reclamation. The objectives of this study were to undertake an inventory of mining activity in the Yukon and to initiate an environmental evaluation of abandonment and reclamation practices, where appropriate, at selected locations.

There are presently no established guidelines or recommended procedures to guide industry or regulatory agencies for the abandonment and rehabilitation of hard-rock or lode mines in the Yukon. As a consequence, members of the mining industry have in the past not been required to assess potential environmental impacts or to undertake any rehabilitation activity upon abandoning a mine. In more recent years, abandonment and rehabilitation plans have been encouraged by regulatory agencies and considered to varying degrees by components of the industry.

2 METHODS

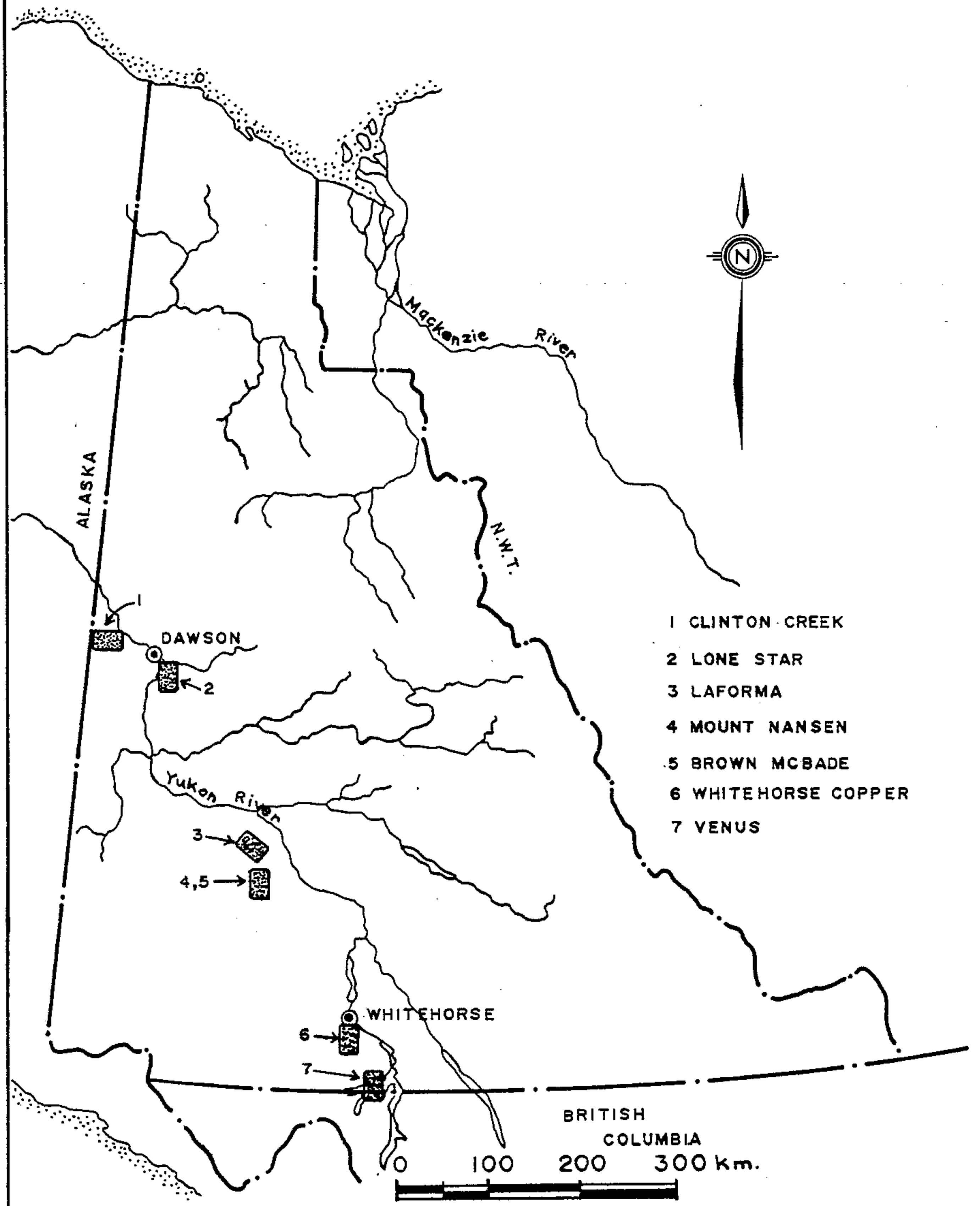
The initial stages of this study involved review of geological and mineral industry reports and discussions with individuals familiar with various abandoned mine sites to determine the nature, date and scale of the mining operation. From these discussions and information review, the parameters for consideration were identified and candidate mines selected for field investigation. An effort was made to select different types of mines and look at a range of time since abandonment to provide a broad perspective rather than emphasizing a particular type of mine or mines that had been abandoned for a specific period.

One of the initial tasks that had to be dealt with was to define the nature of mine abandonment and develop a workable definition. Section 50 and 51 of the Yukon Territory Quartz Mining Act identify the terms and conditions pertaining to the abandonment of a claim. Abandonment in the context of this report includes a claim in "good standing" where the holder of the claim may have discontinued operations on the mine property yet has maintained payments to retain ownership of the claim.

Of the seven specific properties evaluated, six of them are under current ownership and in all six cases, the properties are in the process or anticipated to be in the process of re-assessment for mineral content by the current owners. In cases where claim ownership still exists and assessment work is ongoing, the environmental evaluation considered only the initial workings from when the mine had been active. Figure 1 identifies the location of the seven mines selected for investigation.

2.1 Assessment of Parameters

Identification of environmental impacts associated with mine abandonment involved consideration of parameters such as surface disturbances and water quality within the framework of the following categories:



1 CLINTON CREEK
2 LONE STAR
3 LAFORMA
4 MOUNT NANSEN
5 BROWN MCBADE
6 WHITEHORSE COPPER
7 VENUS

FIGURE 1. Location of study areas.

1. Linear disturbances
    - access routes and tramways
2. Extractive disturbances
    - mine adits, open pits, waste rock piles
3. Impoundment disturbances
    - tailings ponds
4. Intensive land-use disturbances
    - buildings, equipment, machinery and dump sites

The impacts of various types of surface disturbances at the selected sites were assessed on the basis of topography, vegetation, erosion and aesthethics.

2.2 Water Quality Analysis

Appendix I (Table 1) lists collection, preservation and analysis methods for all water quality parameters.

Temperature, pH, depth and conductivity were measured in the field. Dissolved oxygen was measured in the Environmental Protection Service Whitehorse laboratory. All other water quality analyses were done by Laboratory Services, Environmental Protection Service, 4195 Marine Drive, West Vancouver, B.C.

Water samples were analyzed for colour, turbidity, non-filterable residue, filterable residue, total alkalinity, total hardness, total phosphate, nitrite, nitrate, sulfate, chlorine and silica. Separate water samples were taken and analyzed for total mercury and cyanide.

Water samples were analyzed for the following extractable metals:

Aluminum (Al)
Antimony (Sb)
Arsenic (As)
Barium (Ba)
Berillium (Be)
Cadmium (Cd)
Calcium (Ca)
Chromium (Cr)
Copper (Cu)
Iron (Fe)
Lead (Pb)
Magnesium (Mg)
Manganese (Mn)
Mercury (Hg)
Molybdenum (Mo)

Nickel (Ni)
Phosphorus (P)
Potassium (K)
Selenium (Se)
Silicon (Si)
Silver (Ag)
Sodium (Na)
Strontium (Sr)
Tin (Sn)
Titanium (Ti)
Vanadium (V)
Zinc (Zn)

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

$$S' = S\,\frac{P}{760} \quad \text{(APHA et al 1975)}$$

where S' = Dissolved Oxygen (DO) saturation concentration at the in situ temperature and atmospheric pressure.
S = DO saturation concentration at sea level for in situ temperature.
P = Atmospheric pressure in mm of mercury at site elevation.

Then the ratio of DO measured/S', times 100 was calculated to obtain percent dissolved oxygen saturation.

2.3 Sediment

Three replicate sediment samples were taken at all stations except the tailings areas where only one was taken.

Sediment samples were shipped to Vancouver for analysis at Laboratory Services, Environmental Protection Service; 4195 Marine Drive, West Vancouver, B.C.

A description of sediment collection, preparation and analysis methods is given in Appendix II, Table 1.

Samples were analyzed for the same metals as in the water samples.

3 Location and Description of Study Areas

TABLE 1

STUDY AREA	LOCATION	REMARKS
Clinton Creek	64°23'N, 140°43'W	Asbestos, open pit mine located 84 km northwest of Dawson City in western Yukon Territory.
Lone Star	63°53'N, 139°14'W	Silver and gold mine located southeast of Dawson City and north of Dawson Mountain Range near the head of Victoria Gulch on the divide between Bonanza and Eldorado Creeks.
LaForma ✓	62°16'N, 137°07'W	Gold and silver underground mine situated 28 miles west-northwest of Carmacks on the southeast slope of Mount Freegold.
Mount Nansen	62°03'N, 137°10'W	Silver and gold underground mine located in Dawson Range about 30 miles west of Carmacks and about 150 miles northwest of Whitehorse.
Brown McDade	62°03'N, 137°05'W	Silver and gold underground mine located about 3.5 km immediately northeast-east of Mount Nansen mine.
Whitehorse Copper	60°33'N to 60°45'N, 134°53'W to 135°10'W	Open pit and underground copper mine located immediately outside of Whitehorse city limits. Five abandoned pits are considered in this study.
Venus	60°01'N, 134°37'W	Lead-zinc, underground mine located 100 km south of Whitehorse on Windy Arm of Tagish Lake in Coastal Mountain Range.

4 RESULTS AND DISCUSSION

4.1 Linear Disturbances - Analysis

Linear disturbances is a term used to describe transportation systems, such as roads, trails, railroads, tramways, waterways, airways and power transmission lines. For the purpose of this study, roads and tramways will be considered.

The Klondike or Alaska Highways are the primary access routes to all seven mine sites, followed by a secondary roadway to the mine site itself. These secondary routes do not connect with public use roads, their main function being an access route to the mine site.

4.1.1 Linear Disturbances - Environmental Impact. Inadequate drainage facilities and erosion control measures of roadways results in: ponding, flooding, washouts, inundation of vegetation, subsidence, melting of permafrost, the creation of icing conditions and increased highway maintenance (Curran, H.J. Brian and H.M. Etter, 1976). Improper drainage control works may cause damage to ditches and roadways, the undermining of road structures, sedimentation in watercourses and blockage of culverts. Local failure of the road embankment may even occur (Curran, H.J. Brian and H.M. Etter, 1976).

Material used in roadway construction varies; the more porous ones facilitate more rapid drainage preventing ponding on the roadway. Improper crowning of the road causes potholes and deep ruts to develop. Lateral drainage is not facilitated, which results in progressive deterioration of the road.

Drainage requirements over particular sections of roadways are dependent upon: precipitation characteristics, rate of snow melt, size of drainage basins, local topography, soil properties, vegetation cover and road gradients. While erosion control requirements are dependant upon the same factors, they also reflect the need to protect watercourses from sedimentation, reduce dust and improve the general appearance of the roadway (Curran, H.J. Brian and H.M. Etter, 1976). Erosion of roadway materials leads to deterioration of the roadway itself and impacts the peripheral land and watercourses.

The latitude and severe climate of the Yukon, facilitates vast areas of underlying permafrost. The organic or peat layer which forms a protective layer of insulation, is generally thick in the southern boreal forest and decreases in thickness northward although this varies considerably on a local scale. The more ice in the soil, and the thinner the peat layer, the more sensitive the terrain to disturbance (Adam, Kenneth M., 1978). This poses a problem in road construction in the Yukon.

4.1.2 Mitigation of Linear Disturbances. Poor handling of overburden material associated with road construction causes sedimentation in streams and unsightly scars on the landscape. This can be prevented if proper engineering is employed, at the time of initial road construction. If possible, avoidance of areas with permafrost is advised. If unavoidable, a sufficient overlay of fill is necessary to prevent melting, and to allow the soil to remain intact (Lotspeich, Frederick B., 1971).

Revegetation of roadways of permanently abandoned mines as a mitigative measure, faciliates a more aesthetically pleasing area and reduces erosion. Permanent abandonment usually occurs upon exhaustion of the mine's ore body. Mines studied in this report are not in the permanent abandonment category, thus revegetation of mine roadways is not feasible.

Regular maintenance of roadways is essential; if left for extended periods between maintenance, progressive deterioration results. Guidelines for maintenance have been laid down by the Environmental Protection Agency of Alaska (Lotspeich, Frederick B., 1971). These are applicable to the Yukon, which has similar climatic conditions and topography.

Guidelines for Maintenance: (from Lotspeich,Frederick B., 1971)

1. Plan and schedule maintenance on a continuous basis for routine work.
2. Alert all personnel to report any unusual maintenance need, such as a new frost boil or sedimented culvert, before it becomes a serious problem.
3. Keep all cuts and fills that are subject to erosion covered with vegetation or some other material for stabilizing such susceptible areas.
4. Use fertilizers and chemical stabilizers where natural fertility is low to give vegetation a chance to make more rapid growth. Use chemical dust control on paved roads to lessen the hazard of driving and passing on dusty roads.
5. Do not disturb stabilized slopes with maintenance equipment.
6. Keep the road crowned and free of ridges to maintain lateral drainage.
7. Do not move material cleared from ditches to where it can wash into water courses.
8. Allow loessal soils to come to stability by letting the slopes become nearly vertical; this is the most stable slope for these materials. Under such conditions, drainage must be provided and maintained to prevent water from running over the upper edge of the cut bank.

While these guidelines suggest conditions for an optimum level of road maintenance so as to minimize environmental impact, the economic feasibility must also be considered.

4.2 Extractive Disturbances - Analysis

In the context of this study, extractive disturbances is a term used to describe mine adits, open pits, mine waste rock and mill tailings.

Adits: Adits, or mine openings, typical of underground hardrock mines, allow extraction of ore and waste rock and serve as a means of ventilation. At each mining site studied, the adit was visually apparent. The openings are six feet by ten feet in diameter on average and reinforced with large logs.

Structural stability of the adit depends upon time since abandonment assuming the adit has been well maintained during the mine's period of operation. The Lone Star adit which has been abandoned since 1952 (Green, L., 1964) is totally collapsed, (Figure 2) compared to the more recently abandoned adits of other properties (Figures 3, 4, 5 and 6).

Time which has lapsed since original excavation of the adit opening influences extent of revegetation in the immediate area. Excavation of the Lone Star and Brown McDade adits were between 1912 to 1914 (Green, L., 1964) and 1946 (Gleeson, C.F., 1970) respectively. Sedge grasses and willows occur abundantly at both adit areas. More recently constructed adits on the LaForma property (Figures 4 and 5) are not as well revegetated. No vegetation exists at the most recent LaForma adit (Figure 5).

Extreme slope cutting influences revegetative success. Figure 5 of the most recent LaForma adit reveals a slope angle exceeding the angle of repose, leading to slope instability. Instability and continued erosion prevent the necessary anchoring of plant's root systems.

All of the mine adits investigated in this report were left unsealed and no attempts at reclamation were undertaken.

Open Pits: Open pit mining occurred at two of the seven mine sites studied-Clinton Creek, which was an open pit asbestos mine, and Whitehorse Copper, which was an open pit, and presently underground, copper mine. The former has three open pits (Porcupine, Snowshoe and Creek), with the waste rock overburden consisting mainly of argillite. The waste rock has been dumped in two main areas-Clinton dump and Porcupine dump. Several tens of millions of tons have been dumped at the Clinton site, but less than five million tons at the Porcupine

FIGURE 2 NOTE TOTAL COLLAPSE OF ADIT ON THE LONE STAR PROPERTY. REVEGETATION IS PROMINENT.

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FIGURE 3   BROWN MCDADE ADIT. NOTE PROMINENT REVEGETATION OF SLOPE.

never "devegetated"

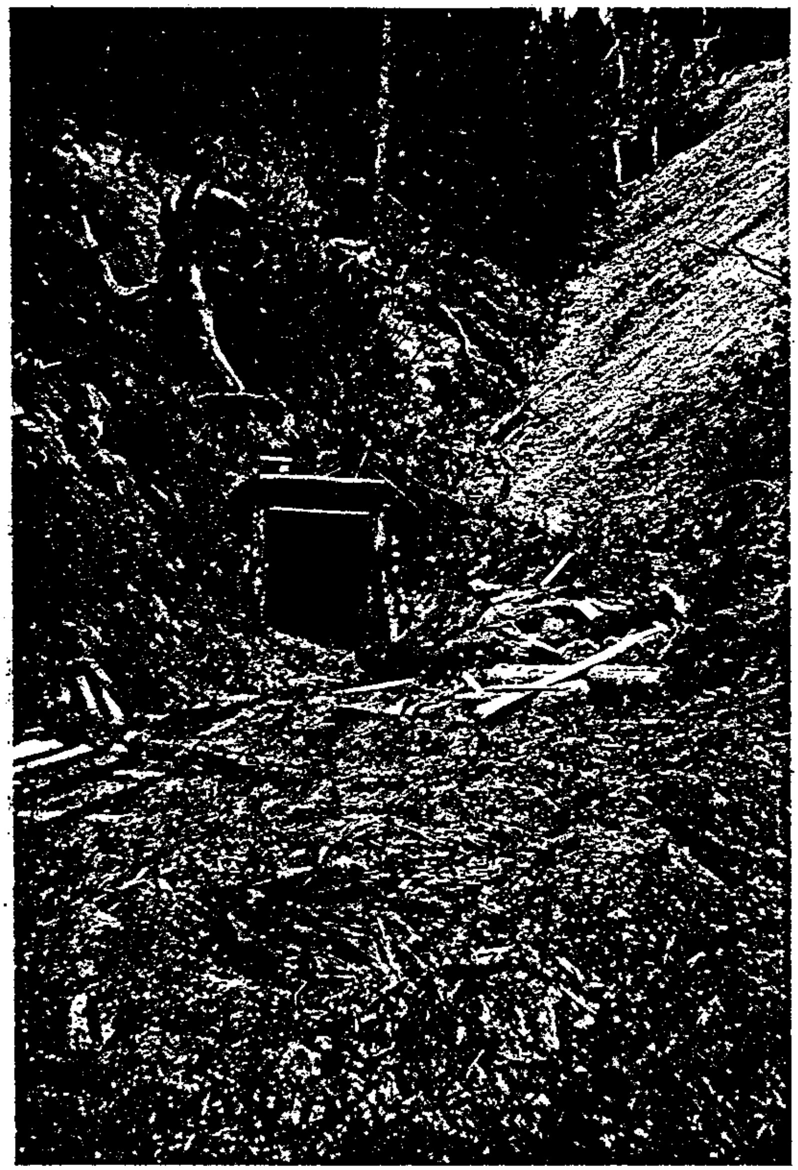

FIGURE 4 ADIT #2 ON THE LAFORMA PROPERTY. SLOPE INSTABILITY IS EVIDENT.

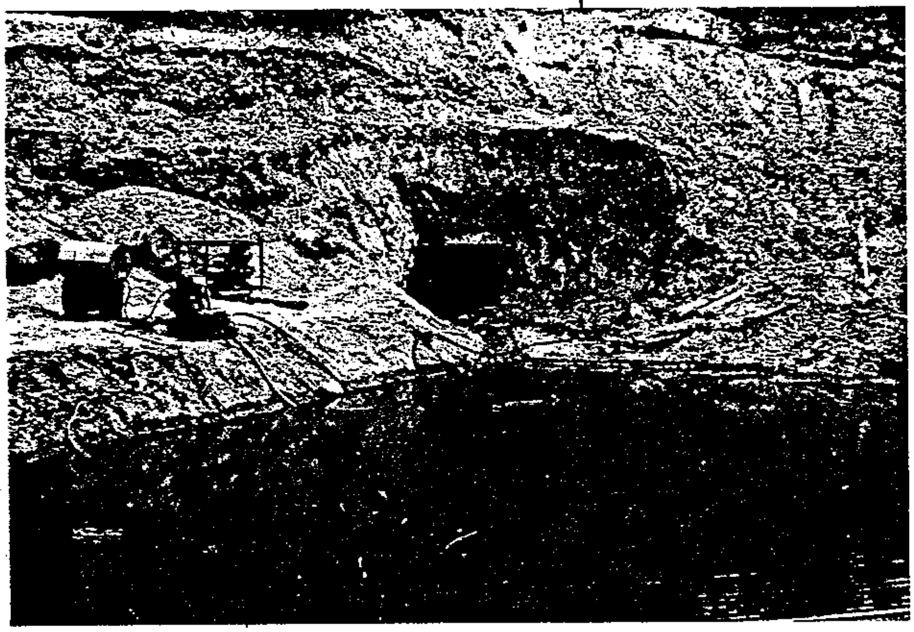

FIGURE 5 MOST RECENTLY EXCAVATED ADIT (ADIT #3) ON LAFORMA PROPERTY. NOTED EXTREME SLOPE CUTTING AND TOTAL ABSENCE OF VEGETATION.

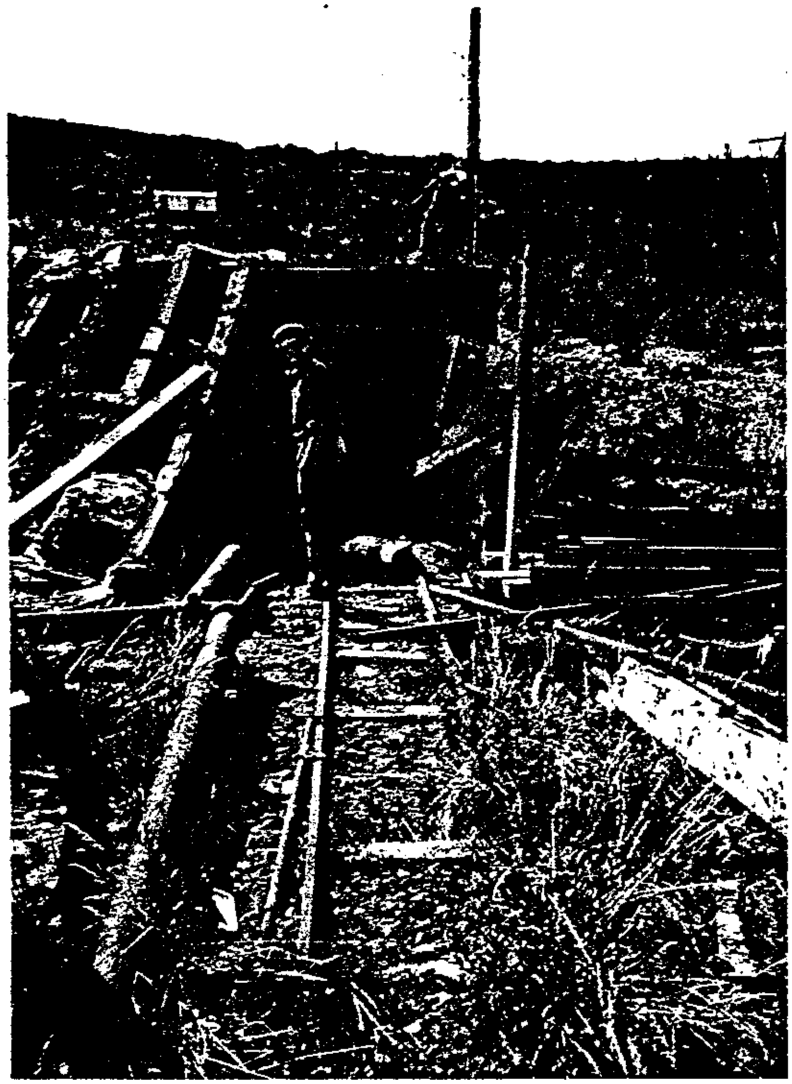

FIGURE 6 MT. NANSEN ADIT. NOTE REVEGETATIVE SUCCESS.

site (Golder & Associates, 1976). Gradual downslope movement of waste rock material resulted in extension of both dumps across the original channels of Clinton and Porcupine Creeks.

Five abandoned pits of the Whitehorse Copper mine site are considered in this study: War Eagle, Arctic Chief, Keewenaw, Black Cub South and Gem. War Eagle, Keewenaw and Black Cub South pits are now partly flooded. An overflow pipe is provided for the Keewenaw pit, allowing run-off to drain into Wolf Creek.

About nine meters of unconsolidated glaciofluvial till make up the walls of the Black Cub South pit. This is extremely prone to erosion (see Figure 7). Build-up of eroded particles at the base of the pit is evident.. An extreme slope gradiant has impeded revegetation. (The angle of repose has been exceeded.) Vegetative roots cannot become established under such adverse conditions.

A combination of shear zones and a phenomenon known as the "Little Chief North Fault" at the Little Chief pit results in slope instability. The southeast bank of the pit is moving downslope at a faster rate than the north-facing slope. Figure 8 shows the difference in altitude of the land on either side of the fault. Activity at the Little Chief pit involved both open pit and underground mining. Original surface elevation of the pit was 2700 feet above sea level, and underground mining occured at 2360 feet above sea level. As a result of the combination of both types of mine workings, slope instability has increased. Cracks and relatively high scarps are seen along the perimeter of the Little Chief Pit (Figure 9). Poor ground conditions at the Black Cub South Pit in combination with abundant groundwater, led to its premature closure in 1971, before the small bottom level had been mined.(Tenney, D., 1981)

Open pit design includes establishment of "safety berms" - providing a bench for interception of material eroding from high angle pit walls, thus protecting the bottom of the pit from falling rock. The Keewenaw pit, which has only a few benches, reveals a talus slope, as does the Arctic Chief pit.(Figure 10)

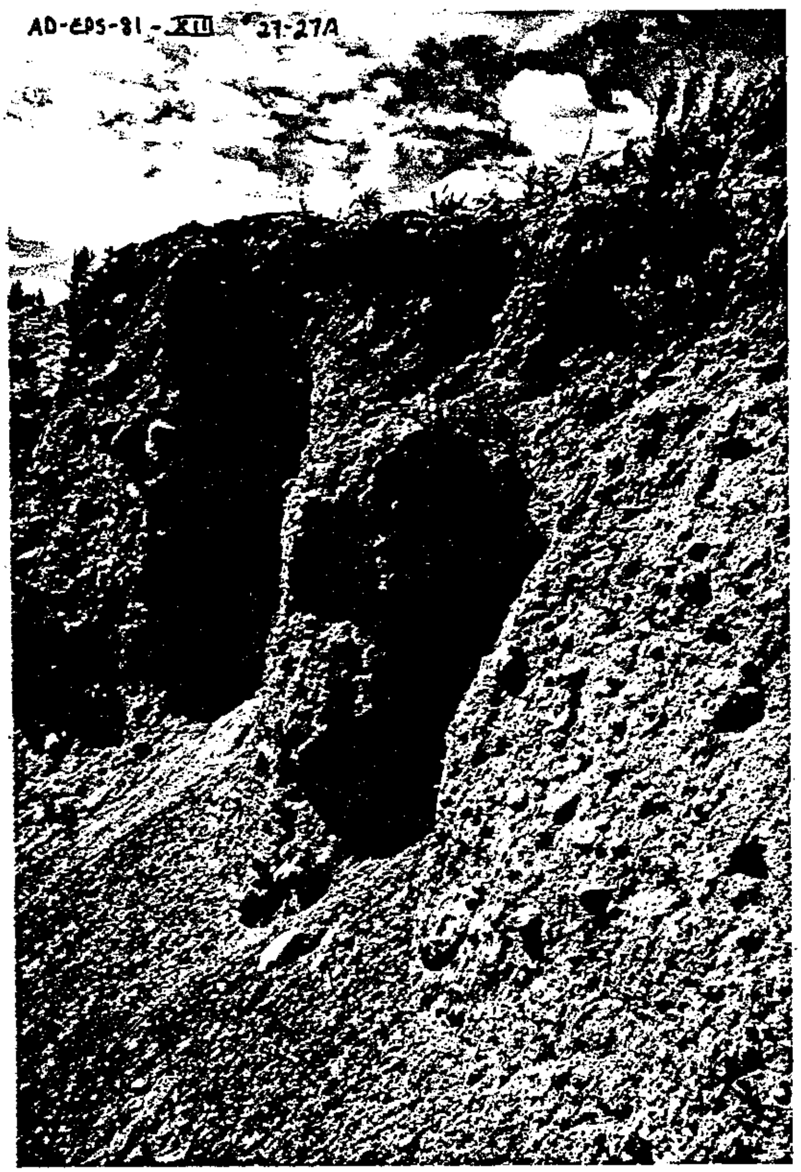

FIGURE 7 GLACIOFLUVIAL TILL IS EXTREMELY PRONE TO EROSION AS SEEN OF PIT WALLS AT WHITEHORSE COPPER MINE.

FIGURE 8 THE "NORTH FAULT" ZONE AT THE LITTLE CHIEF PIT OF WHITEHORSE COPPER MINE SITE.

FIGURE 9 CRACKS ARE EVIDENT ALONG THE PERIMETER OF THE LITTLE CHIEF PIT.

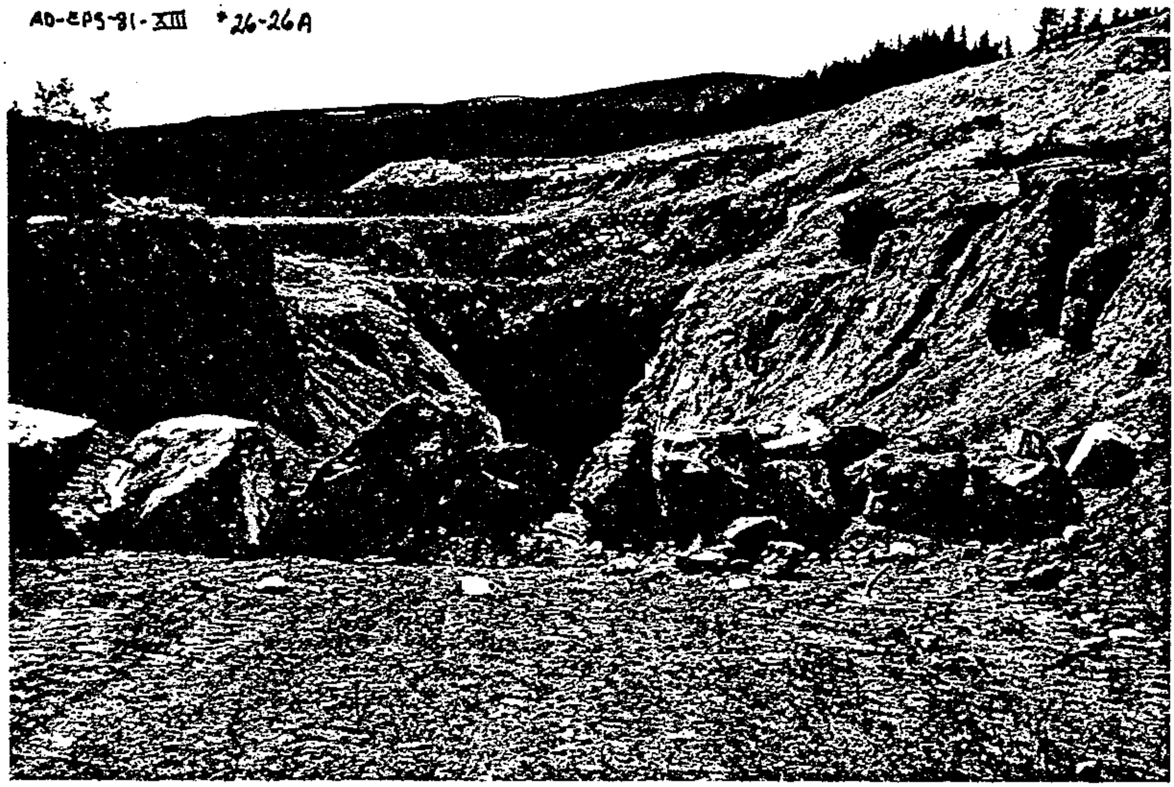

FIGURE 10 ABANDONED PIT ON WHITEHORSE COPPER PROPERTY SHOWS BENCHES. NOTE TALUS SLOPE.

Waste rock Piles: Another extractive disturbance to be considered are waste rock piles. Waste rock piles include all waste embankments other than tailings or ore resulting from a mining operation (Coates, D.F. and Y.S. Yu (eds), 1977). The general trend in Canada to mine lower grade ore has resulted in greater waste rock piles (Coates, D.F. and Y.S. Yu (eds), 1977).

These embankments which are usually located on sides of hills or valleys, are not water impounding structures. The primary function of a waste rock embankment is to store waste material in a designated area and ensure public safety (Coates, D.F. and Y.S. Yu (eds), 1977).

Economically, the closer the distance of the waste pile to the mine, and the closer the top of the waste pile to the excavation, the cheaper the operating costs. This is of primary consideration to the miner in determining location of the waste rock pile.

4.2.1 Extractive Disturbances - Environmental Impact

4.2.1.1 Adits. An open adit bearing an exposed reactive - sulphide rock face is predisposed to leaching of acid and/or heavy metals, should it come into contact with a water supply. If toxic levels are reached, it could threaten adjacent aquatic and biological resources.

If extreme slope cutting is employed upon adit construction, slope instability and erosion occur. When slope steepness exceeds the angle of repose, revegetative ability is impaired, and aesthetically, the area is depressed. Depending upon particle size and type of eroded soil, nearby watercourses may be infiltrated with sediment, and aquatic life affected.

Upon abandonment, open adits (making shafts readily accessible) pose health hazards to man and wildlife. Toxic chemicals found in closed containers or shattered on the ground at some mine properties could also threaten wildlife and aquatic resources.

4.2.1.2 Open Pits. Open pits with wall rock containing substantial quantities of reactive sulphide minerals can cause serious water pollution problems (Arkay, Katherine E., 1975). The severity of the potential water pollution problem depends upon the nature of the exposed rock face. When the ore body is sharply defined, excavation beyond the ore body leaves a "sulphide-free" rock face. However, a pit wall with a continuous gradation from ore to host rock renders it impossible to clean away the entire sulphide rock face. The pit face would be rich in minerals and sulphides. Reactive sulphide minerals such as pyrite, pyrrhotite, chalcopyrite, sphalerite, marcasite and arsenopyrite generate acid upon chemical oxidation in the presence of oxygen and water.

Rate of acid generation is dependant upon abundance of reactive sulphide minerals in the pit rockface and grain size of the reactive sulphides. Net acid production is directly related to the natural neutralizing capacity of the rock (Arkay, Katherine, E., 1975). In the presence of a bacterium, Thiobacillus ferrooxidans, acid generation can occur biochemically. This bacteria obtains its energy for growth from the oxidation of reduced sulphur compounds (sulphides) and ferrous iron. It requires oxygen, water, carbon dioxide, ammonia, phosphorus and trace amounts of nutrients such as calcium and magnesium to function. In the case of pyrite, the net reaction is considered in Equation 1 (Scott, J.S. and K. Bragg, (eds.), 1975):

$$4FeS_2 + 15O_2 + 14H_2O \longrightarrow 4Fe(OH)_3 + 8H_2SO_4 (1)$$

This reaction involves complete hydrolysis of the ferric ion, yielding two moles sulphuric acid per mole pyrite. In actuality, not all the iron precipitates as iron hydroxide, but as an iron sulphate jarosite type material represented by the formula $AFe_3(SO_4)_2(OH)_6$, where A can be H^+, Na^+, K^+, etc., (as seen in Equation 2) (Scott, J.S., and K. Bragg (eds.) 1975). This results in production of 1.33 moles of acid per mole pyrite.

$$6FeS_2 + 22\tfrac{1}{2}O_2 + 15H_2O \longrightarrow 2HFe_3(SO_4)_2(OH)_6 + 8H_2SO_4 (2)$$

Some reactive sulphide minerals are more reactive than others, yielding greater amounts of acid per mole of mineral.

Open pits with a non-reactive material rock face pose no major environmental water pollution problem. They may be safety hazards though, with the effects of erosion, rotational sliding and shearing all contributing.

4.2.1.3 Waste Rock Piles. Topography of the area affects the waste rock dump's stability. Flat surfaces offer a more stable condition.

A typical form of slope instability known as rotational sliding, is caused by excessive slope steepness for that particular waste material, and/or overloading of a weak foundation. An increased pore water pressure beyond a critical level within the embankment or its foundation triggers instability (Coates, D.F. and Y.S. Yu (eds), 1977). The first indication of rotational sliding is usually a tension crack at the top of the failure surface (Figure 11). Slumping of material on slope side of the crest and upheaval of soft foundation material or bulging at the toe may also occur.

Figure 12 shows effects of plane shear on a waste embankment. Foundation material is not soft as in rotational sliding, but the same overall effect of slope instability exists (Coates, D.F. and Y.S. Yu (eds), 1977).

"Shear strength" of waste material - defined as the maximum resistance of a soil to shearing stresses, is determined by the cohesive and internal friction properties of those particles. Shape of waste material particles also influences its shear strength. Slabby-shaped pieces tend to slide when dumped upon each other (Coates, D.F. and Y.S. Yu (eds), 1977) leading to extreme instability. Generally, the coarser the material, the greater possible slope of the embankment. Potentially unstable particles include peridotite, olivine, serpentine, sercite, urica and talc, which are all typically found in the Yukon. Particles of the Clinton Creek mine are made of black phyllite, platy black limestone, grey argillite and brown weathering micaceous, gritty quartzite (Sinclair, 1975) thus being very susceptible to sliding.

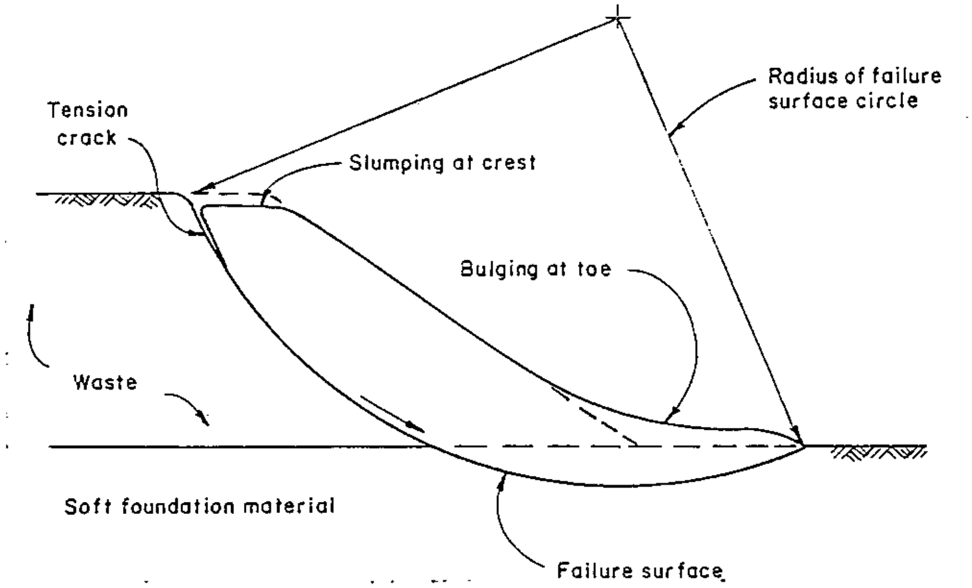

FIGURE 11 ROTATIONAL SLIDING

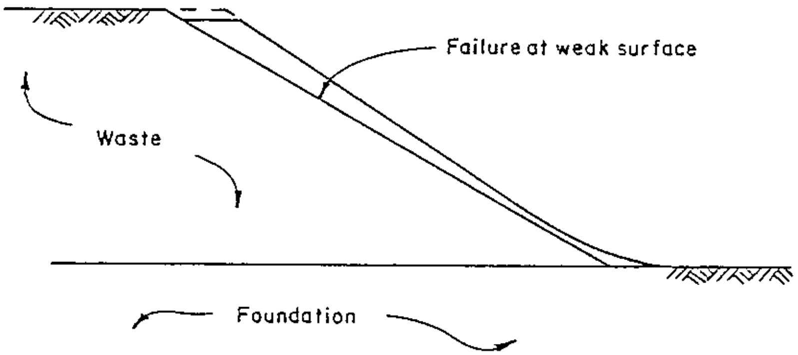

FIGURE 12 PLANE SHEAR

In the spring of 1974, the Clinton Creek waste rock pile slid downslope, blocking a portion of Clinton Creek, resulting in the formation of Hudgeon Lake upstream of the toe of the dump. That same spring, a large section of the asbestos tailings moved downslope blocking Wolverine Creek, forming Wolverine Lake (Landucci, J.M., 1978).

In 1981, a study performed at the Clinton Creek waste dump showed fresh tension cracks in the waste rock pile. The slope near the creek was then moving at a rate of 1.7 to 5 feet per year horizontally, and vertical movement was greater (Hardy Associates Ltd., 1981). The Wolverine Creek tailings pile exhibits wide open cracks and almost vertical scarps through its north lobe. Some of the benches cut into the pile in 1978, show numerous cracks and scarps (Figures 13 and 14). The tailings pile and waste rock pile have not reached equilibrium yet; they are still unstable.

Of the two waste rock dump sites at LaForma, the 1938 dump, with a slope of 40° supports no vegetation (Figure 15). Similarly, the steeply sloped waste rock pile of 1965 is unvegetated (Figure 16).

The Lone Star mill was only operated between 1912 and 1914, thus giving rise to a rather small waste rock pile. It is located on the slope of the Gulch, but erosion is not significantly extensive. Even though the slope angle is 40°, revegetation has been facilitated after 68 years (Figure 17). A low canopy of willow and a mid-canopy of aspen and white spruce has become established.

Erosion can lead to waste rock embankment instability (Coates, D.F. and Y.S. Yu (eds), 1977). Extensive rill erosion of the waste rock at the Brown McDade property poses an environmental problem for aquatic resources (Figure 18).

Small channels of water flow over the tailings, carrying particles along. Sedimentation into nearby channels of water can result. Figure 19 shows a severe case of sedimentation on the Clinton Creek property. Other possible environmentally detrimental consequences of erosion are listed, (Environmental Protection Agency, 1976):

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FIGURE 13 CLINTON CREEK TAILINGS IN FOREGROUND AND WASTE ROCK PILE IN MIDGROUND. BOTH EMBANKMENTS ARE UNSTABLE. NOTE CRACKING IN LOWER LEFT HAND CORNER.

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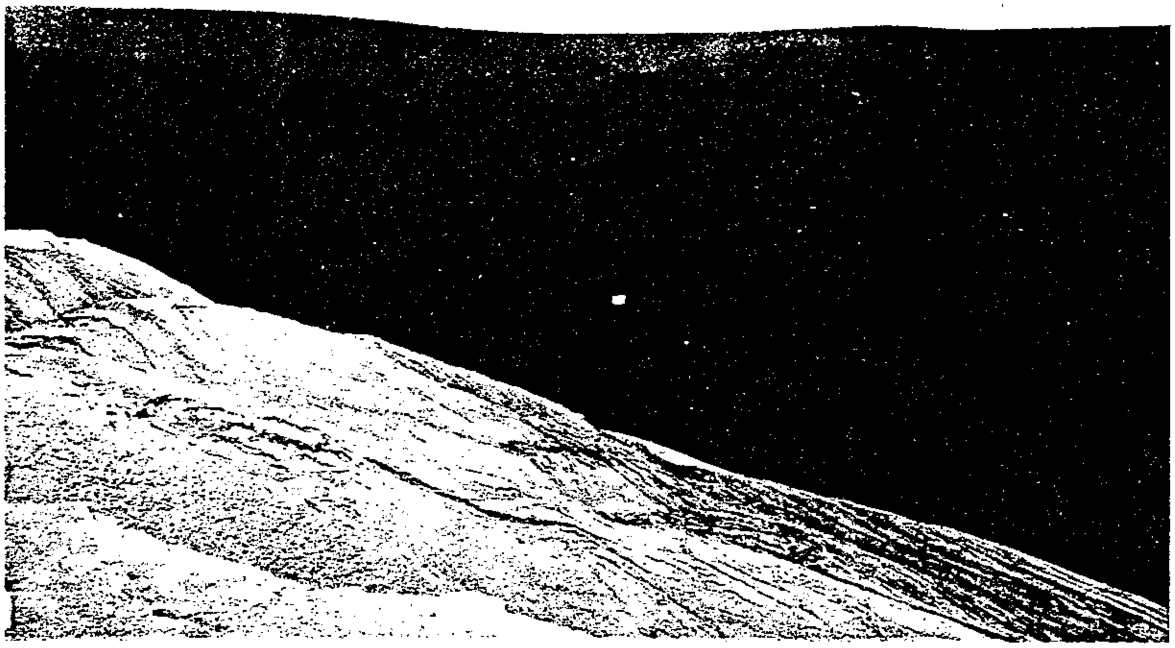

FIGURE 14 CLINTON CREEK TAILINGS PILE. SLOPE IS MOVING DOWNSLOPE AS IS EVIDENT BY THE CRACKS ON THE PILE SURFACE.

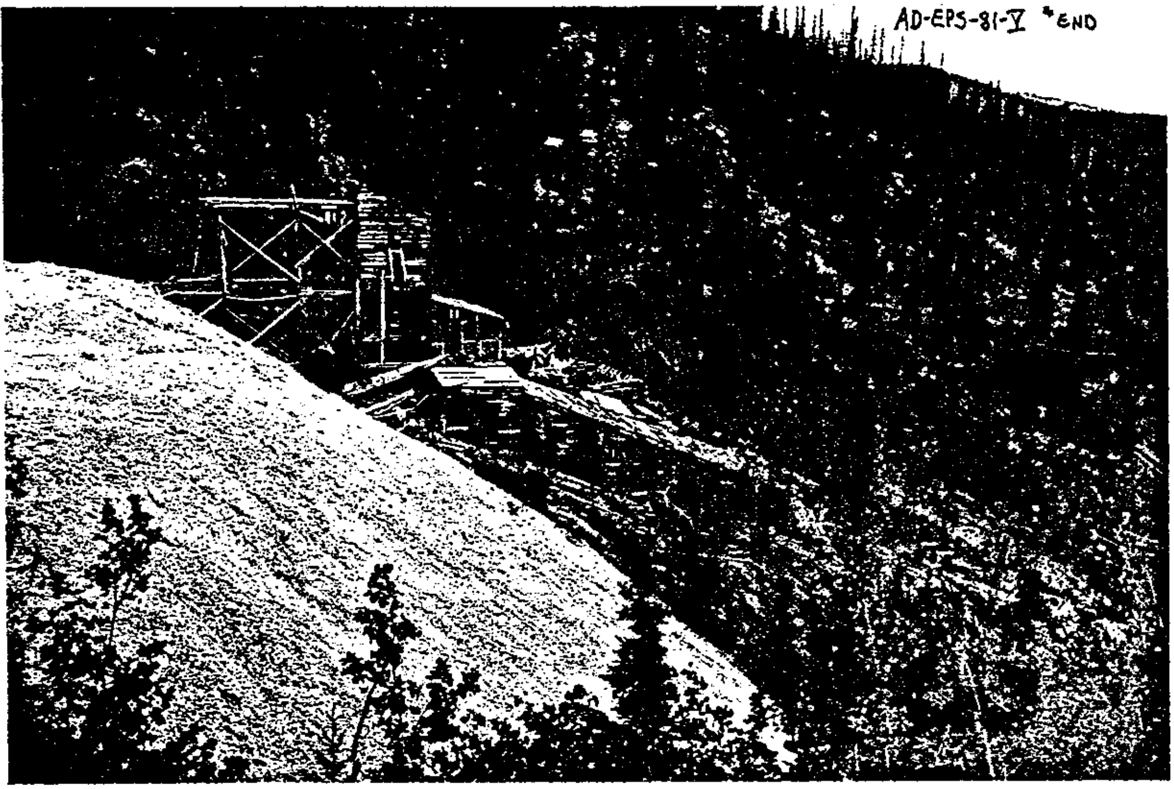

FIGURE 15 THE 1938 LAFORMA TAILINGS PILE, WITH A SLOPE OF 40° SUPPORTS NO VEGETATION.

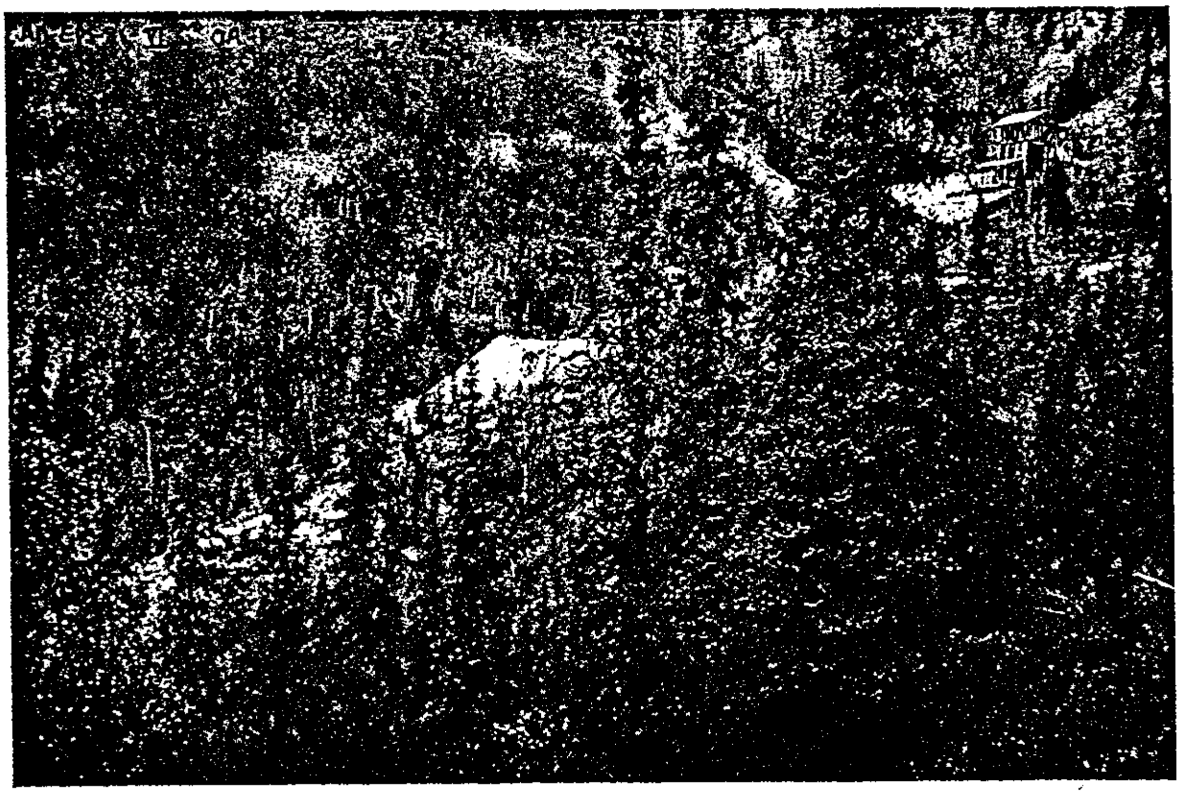

FIGURE 16 SECOND TAILINGS PILE IN PROXIMITY TO THE ORIGINAL MILL ON THE LAFORMA PROPERTY.

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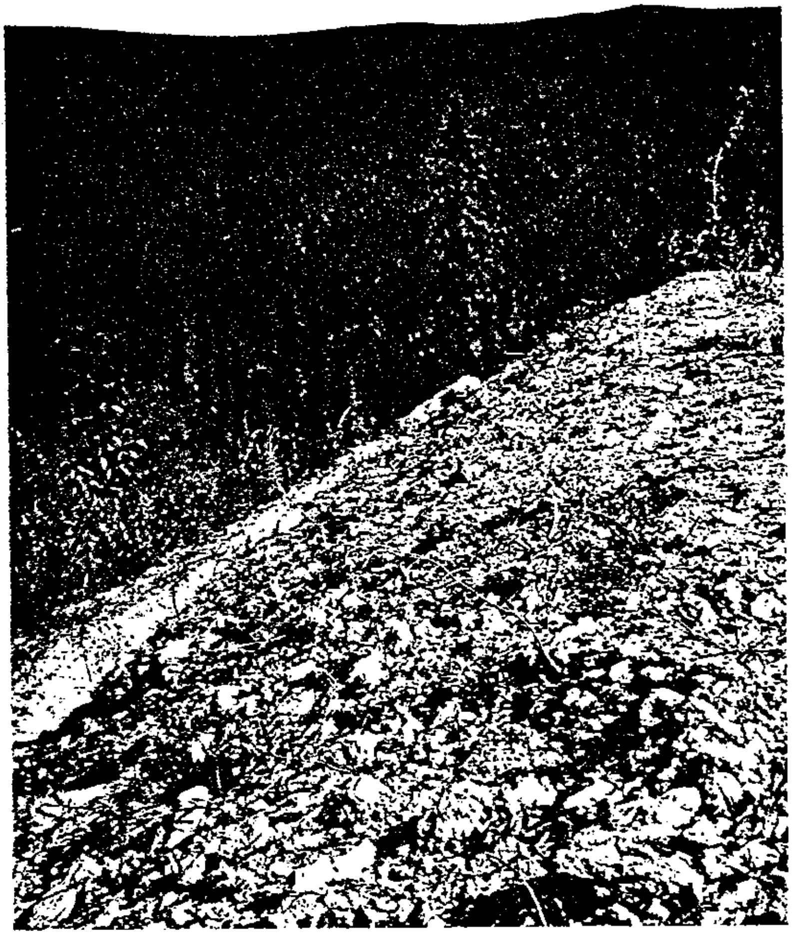

FIGURE 17 WITH A SLOPE OF APPROXIMATELY 40°, THE WASTE ROCK PILE ON THE LONE STAR PROPERTY SUPPORTS VEGETATION.

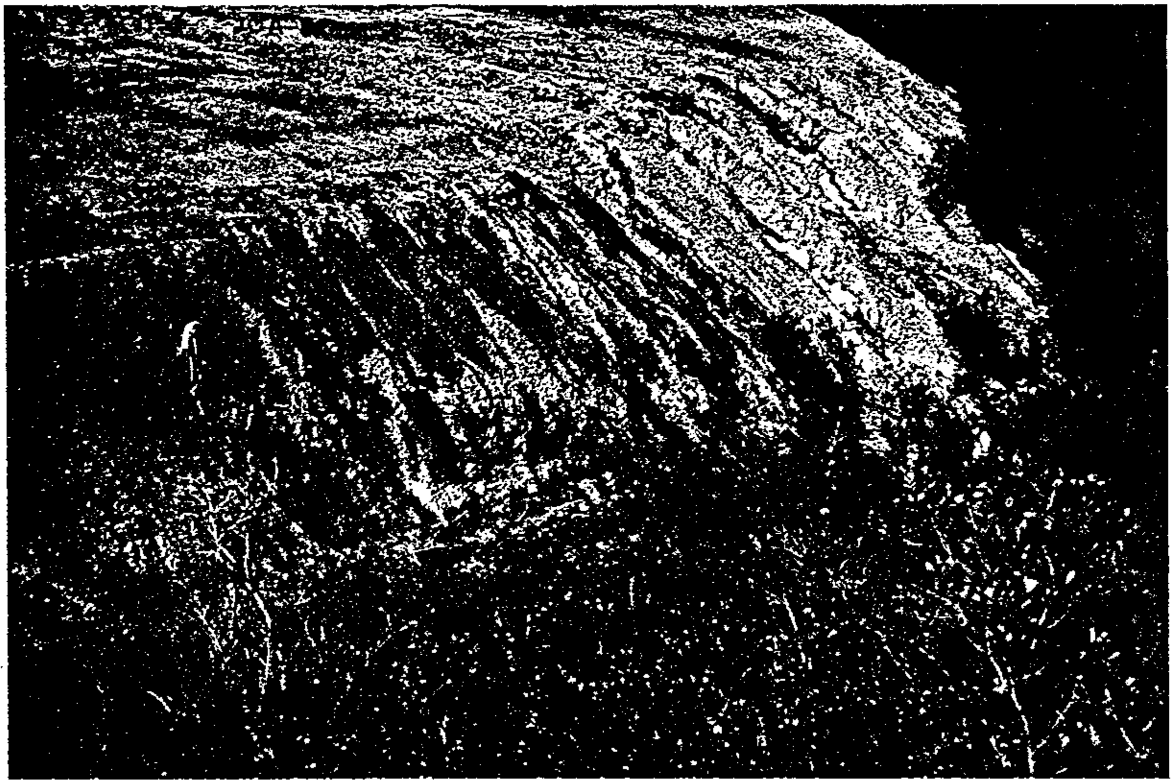

FIGURE 18 EXTENSIVE RILL EROSION ON THE SLOPE OF THE WASTE ROCK PILE OR BROWN MCDADE MINE - NEXT TO THE MOUNT NANSEN PROPERTY.

FIGURE 19 A CASE OF SEVERE SEDIMENTATION ON THE CLINTON CREEK PROPERTY. NOTE LACK OF REVEGETATION.

- Occupies water storage in reservoirs
- Fills lakes and ponds
- Clogs stream channels
- Settles on productive land
- Destroys aquatic habitat
- Creates turbidity that detracts from recreational use of water and reduces photosynthetic activity
- Degrades water for consumptive uses
- Increases water treatment costs
- Damages water distribution systems
- Acts as a carrier of other pollutants (plant nutrients, insecticides, herbicides, heavy metals)
- Acts as a carrier of bacteria and viruses.

4.2.2 Mitigation of Extractive Disturbances

4.2.2.1 Adits. In all cases, the mine adits studied showed no apparent attempts at reclamation. To suggest complete reclamation of the adit's collar and adjacent area would be unfeasible, since the re-evaluation of abandoned mine properties is quite common in the Yukon.

Chemical sealing of exposed reactive-sulphide rock prevents interaction of the rock face with water, which prevents leaching. However, at present, no economic seals are available (Arkay, Katherine E., 1975). While the surface can be sealed, it is difficult to form a permanent seal, especially at that point where the sealant terminates on the rock face. This is a perpetual treatment and thus economically unfeasible as a mitigative measure.

Diversion of flowing water from the mine adit entrance will minimize possible leaching of metals and/or acid from a reactive sulphide rock face. Drainage from the adit should be collected in a pond and treated if necessary, before entering nearby watercourses.

Recontouring and revegetation of slopes that were steeply cut upon adit construction would provide a more aesthetically pleasing and physically stable area. Adit collars should be securely supported with logs and protected by a fence or gate disallowing entrance. As a safety precaution, the mouth of the adit should also be sealed as is required in British Columbia (Ministry of Energy, Mines and Petroleum Resources for the Province of British Columbia, 1979).

4.2.2.2 Open Pits. Backfilling of open pits with non-reactive sulphide mineral wasterock, should be employed as a safety measure. The area could then be spread with overburden and revegetated. Depending on distance between the pit and waste rock pile, this could prove to be expensive. Alternatively, for economic reasons, only hazardous areas of the pit could be fenced in. Fencing could also be employed in areas where steep escarpments occur naturally in the topography.

Often with man-made pits, severe cracking develops, where this would not occur with a natural rock cliff. To avoid soil creep and slope instability, rehabilitative measures should be taken.

Acid production from open pit walls containing reactive sulphide minerals, can be reduced by elimination of one of the necessary components for acid generation - water, oxygen or the bacterium, Thiobacillus ferrooxidans. Diversion of waterflow around the pit is recommended. Oxygen depletion can be accomplished by sealing the potentially reactive minerals within the pit with water, a layer of non-reactive sediment or a vegetative layer which utilizes oxygen. Addition of bactericides to pit water has not been successful to date, due to inadequate mixing of pit water and rapid recovery of bacteria (Arkay, Katherine E., 1975).

The "War Eagle" pit of the Whitehorse Coppermine is being used as the city's garbage dump (Figure 20). It has been in continual use since later summer of 1975 (Reid, Crowther & Partners Ltd., 1982). Two access roads cut down into the pit have been filled with garbage; there is no dumping directly into the pit. About three years ago, rising water reached the toe of the dump. Since then, more and more garbage has been submerged, potentially maximizing leachate generation (Reid, Crowther & Partners Ltd., 1982). Leachate is presently entering and contaminating the water in the War Eagle pit. The pit itself could not be used as a landfill site until water had been removed and treated, and the pit floor sealed, preventing groundwater entrance. Runoff would also have to be controlled (Reid, Crowther & Partners Ltd., 1982). Economically, this proposal would be rather expensive. Without these protective measures, however, the pit would be environmentally unfit for use as a landfill site.

Figure 21 of the Gem pit (of Whitehorse Copper mine) shows how only the overburden was removed, then excavation was terminated. It would be more aesthetically pleasing and biologically productive if the overburden was respread and the area revegetated, (or at least revegetated).

4.2.2.3 Waste Rock Piles. Stablization of waste embankments to minimize environmental impact is essential. Recontouring and revegetation reduces slope instability and erosion, as well as providing a more aesthetically pleasing area. In some areas, where revegetation is not possible due to toxic wastes, chemical sealing followed by a generous application of overburden may be necessary to prevent evapo-transpiration of the toxins into the overlying vegetation. This has been suggested for the serpentine asbestos tailings at Clinton Creek (Hardy Associates Ltd., 1978). In contrast though, the mine's argillite wasterock appears to be a good substrate for vegetation - although recontouring is still necessary.

Segregation of reactive and non-reactive sulphide wastes minimizes total amount of material to treat. Highly reactive sulphide waste must be sealed either chemically or physically. Chemical sealing of the reactive wastes, by means of latex emulsions, concrete etc., or physical sealing with soil or some kind of mulch, allows initial establishment of vegetation. When employed as the only mitigative measure, sealing is economically unfeasible. Constant erosion lends to repeated application. In conjunction, with revegetation, sealing is more permanent (Arkay, Katherine E., 1975). In an area unsuited to vegetative growth because of harsh climatic conditions or scarcity of

FIGURE 20 ABANDONED "WAR EAGLE" PIT ON WHITEHORSE COPPER IS BEING USED FOR THE WHITEHORSE CITY DUMP.

AO-EPS-81-XIII * 12-12A

FIGURE 21 GEM PIT OF THE WHITEHORSE COPPER PROPERTY. NOTE ACCUMULATION OF GROUNDWATER. AREA COULD BE COVERED WITH OVERBURDEN AND RESEEDED, AS A MITIGATIVE MEASURE.

soil cover and plant nutrients, chemical sealing may be employed as a means of mitigation.

Vegetation prevents erosion by slowing surface water run-off, and reduces seepage by increasing evapo-transpiration (Arkay, Katherine E., 1975). Vegetation builds up a soil profile which by increasing surface retention of water, makes this water available for evaporation (Skelly and Loy, 1973). This can result in a net decrease in the amount of water entering underlying waste rock material. This would reduce leaching from reactive sulphide mineral waste rock which is capable of generating acid. Surface water is also used by vegetation in great quantities for life processes. Oxidation of underlying reactive sulphide minerals is reduced, as the soil profile also acts as an oxygen barrier, since soil bacteria utilize the oxygen.

While vegetation does serve to decrease water contamination, it does not totally alleviate it. A certain amount of leaching inevitably occurs. A solid, self-perpetuating vegetation cover could be established on waste rock material containing plant toxins, by using a large amount of overburden in conjunction with chemical sealing. It may be of advantage to use a special type of overburden consisting of an overlying fine-grained layer and an underlying coarse-grained layer (Arkay, Katherine, E., 1975). The upper layer might serve to impede movement of water downwards, thus reducing leaching. The underlying, coarse-grained layer would reduce the capacity of evapo-transpiration by the process of upward capillary movement of contaminated water. This would reduce the probability of destruction of overlying vegetation, by any toxic acids generated.

Figure 22 shows use of waste rock for a roadbed on the Whitehorse Copper property. Figure 23 allows for a comparison of vegetation on the waste rock pile side of the roadway and the natural bank on the opposite side of Wolf Creek. Waste rock particle size and lack of adequate substrate does not lend itself to revegetation of the area.

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FIGURE 22 WASTE ROCK PILE USED AS A ROADBED ON THE WHITEHORSE COPPER PROPERTY.

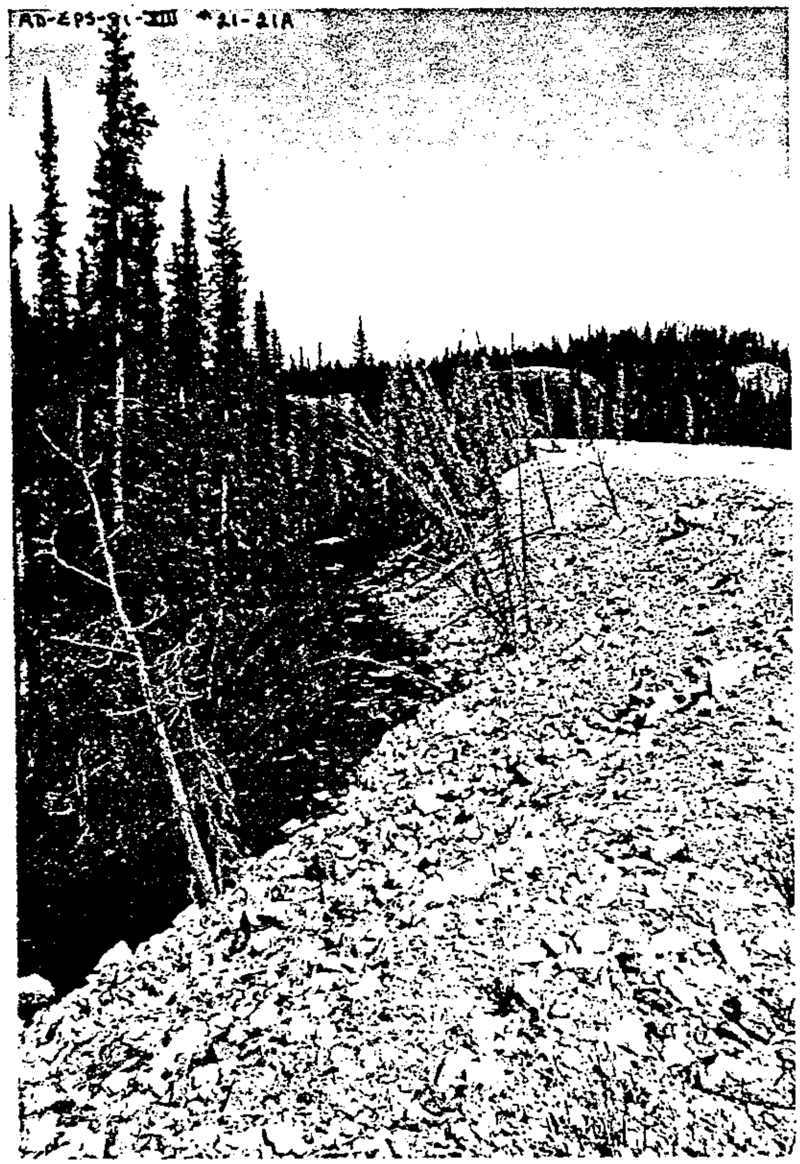

FIGURE 23 COMPARE STREAM BANKS OF WOLF CREEK ON WHITEHORSE COPPER PROPERTY IN TERMS OF VEGETATION.

4.3 Impoundment Disturbances - Analysis

Tailings ponds are waste disposal areas containing finely sized particles which are discarded following the concentration and recovery of the desired mineral values from the ore body (Marshall, I.B., 1982). Mills using water in the recovery process transport the tailings as a slurry to the tailings pond. The Clinton Creek mill used a dry process, and dumped the tailings into a pile.

The tailings pond functions to provide sufficient retention time to allow settling of solid particles. Depth of pool, surface area, distance between point of tailings and effluent discharge, and wave action are all important factors to consider.

4.3.1 Impoundment Disturbances - Environmental Impact. When a mine is in operation, the tailings effluent is monitored and supporting structures (berms) are maintained. Ideally, upon abandonment, the tailings area should be maintenance-free. However, the Venus tailings pond (Figure 24) shows inadequate condition of the berm, even though has been supported with crossbeams and lined with plastic. While it suffices to contain the present tailings pond which has dried up considerably (Figure 25), it would not be adequate if the water level in the pond increased. In 1971, a breach in the tailings pond at Venus mine during the winter months casued about 100 tons of tailings to flow into Tagish Lake (Jack, M.E., 1981).

The second of the three tailings ponds of Mount Nansen is seen in Figures 26 and 27. The embankment has been breached and the pipe leading to the third tailings pond is severed.

When a pond is overtopped with water, breaching of the tailings embankment can occur, and in some cases may cause washout of the entire embankment. Overtopping is probably the most common cause of dam instability.

Another problem associated with impoundment dams is piping.This involves the transport of solid materials in the seepage water either through or under the dam (Coates, D.F. and Y.S. Yu (eds), 1977).

FIGURE 24 BERM OF THE TAILINGS POND AT VENUS MINE HAS COLLAPSED.

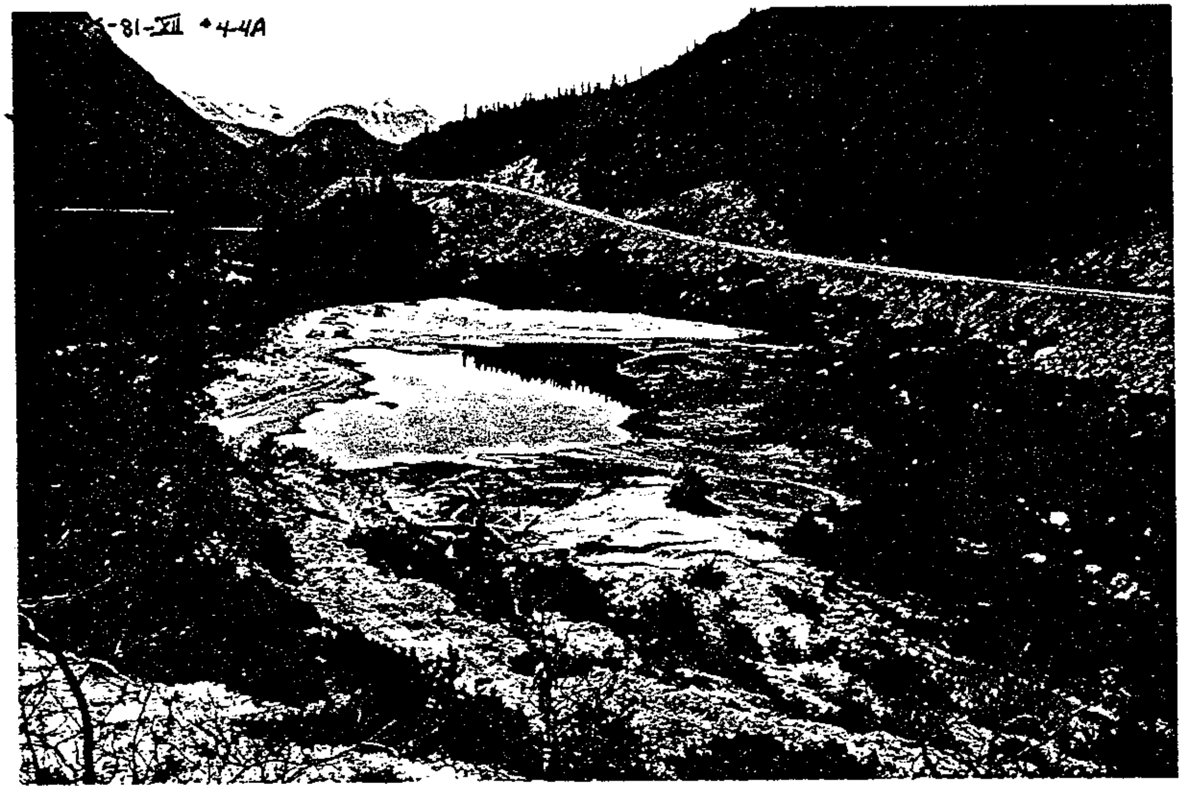

FIGURE 25 TAILINGS POND OF VENUS PROPERTY. WHILE IT HAS DRIED UP CONSIDERABLY SINCE TIME OF ABANDONMENT, HIGH WATER LEVELS IN THE POND (DURING SPRING MELT) MAY FLOW OVER THE BREACHED BERM (IN UPPER LEFT-HAND CORNER OF POND).

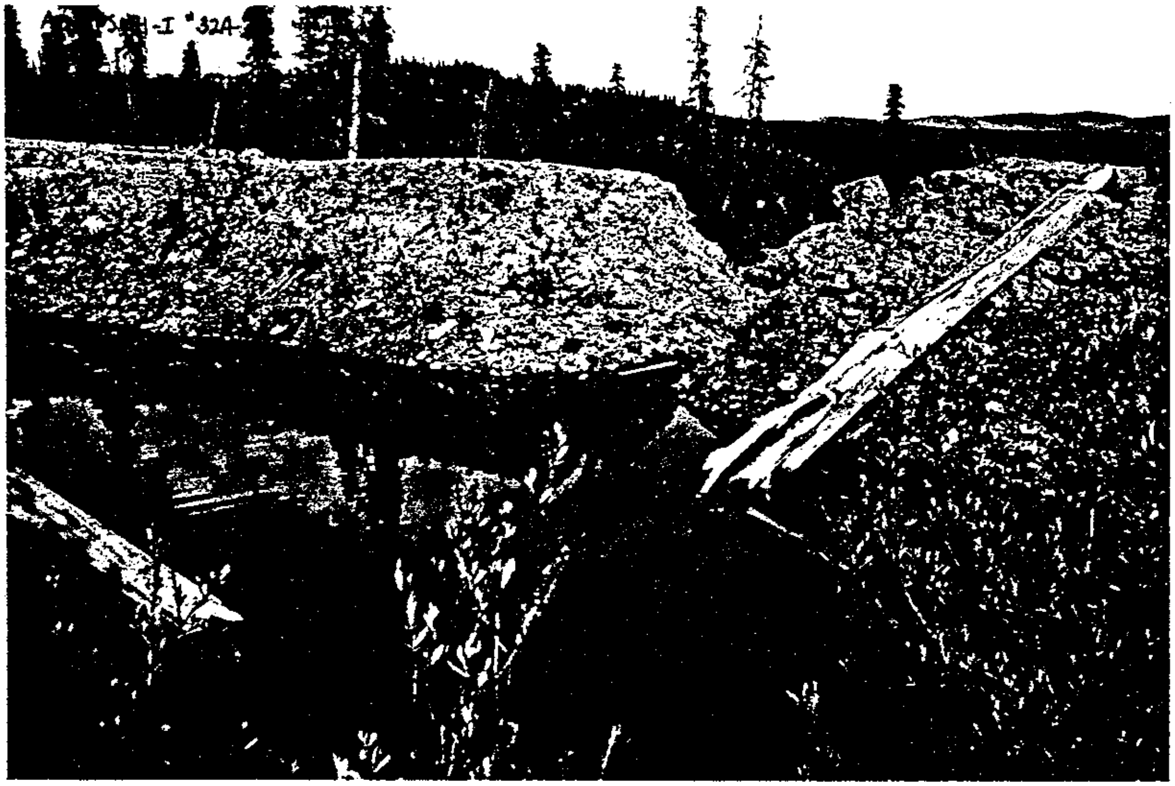

FIGURE 26 SECOND TAILINGS POND AT MOUNT NANSEN SHOWS A BREACHED EMBANKMENT.

FIGURE 27 A SEVERED PIPE CONNECTING TAILINGS PONDS 2 AND 3 AT THE MOUINT NANSEN PROPERTY IS EVIDENT. (LOWER RIGHT HAND CORNER).

A kind of "pipe" extending progressively under the embankment may develop when sufficient water has passed through. Upon excessive water flow, breaching of the dam occurs.

Figures 28 and 29 show erosion of the tailings pond at the Venus mine. An insufficient overflow system led to the oversaturation and eventual erosion of the tailings through the former decant. The decant pipe has been lowered to the bottom of the pond now - serving more as a drain than a decant pipe. An example of a different system is shown in Figure 30.

Construction of the berm affects the degree of impoundment impact on the environment. In an area where annual precipitation exceeds evaporation, the berm must be constructed to compensate for excess water accumulation. The containment area must also be large enough to compensate for precipitation accumulation, and a drainage mechnanism must be provided to allow water release after a significant settling time. If settling time is inadequate to allow release into a nearby natural body of water, another containment area for treatment of the still-contaminated water must be provided. Impoundment of tailings is necessary for a variety of reasons, (Arkay, Katherine E., 1975):

- primary settling area for gangue
- treatment tank of pH adjustment or chemical precipitation
- water storage area
- surge tank for controlling discharge into public waters
- investment storage, since can be reclaimed for future use.

Settling of the fine suspended solids and sediments is essential. If allowed to pass directly into a nearby body of water, there is an immediate increase in turbidity of the water. Productivity of plant life suffers due to decreased light penetration, and aquatic animals are directly affected by the diminished food source. Secondarily, respiration of aquatic animals is impaired, because spiracles, breathing tubes and/or gills can no longer function properly. Benthic invertebrates and fish, abundance and diversity are directly affected. As a treatment tank, a tailings pond operates to contain contaminated chemical and sulphide reactive waste material for

FIGURE 28 EROSION ON THE MOST EASTERLY SIDE OF TAILINGS POND ON THE VENUS MINE PROPERTY. NOTE THAT ZONE IS NOT MAINTENANCE FREE.

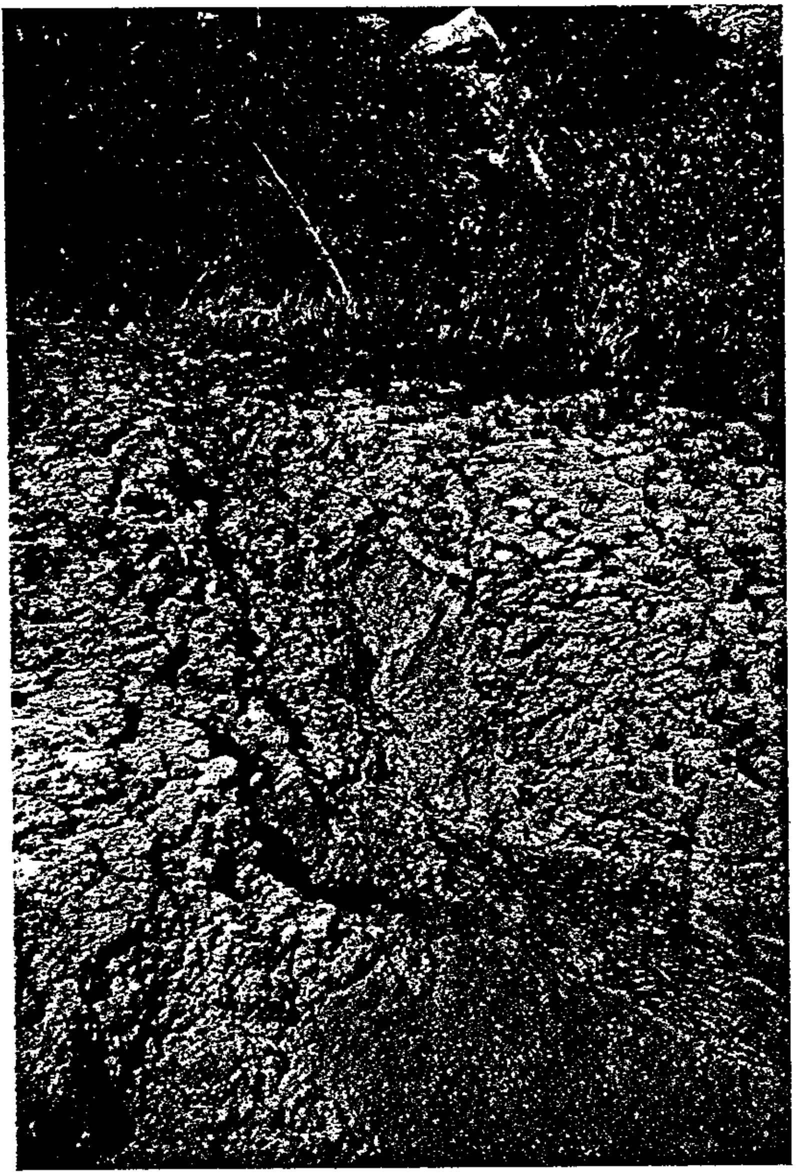

FIGURE 29 NATURAL BREACH UPSLOPE OF THE VENUS MINE TAILINGS. SEVERE GULLY EROSION IS EVIDENT.

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FIGURE 30 MOUNT NANSEN OVERFLOW SYSTEM MINIMIZES EFFECTS OF HIGH WATER BUILD-UP IN THE IMPOUNDMENT AREA. BANK STABILITY IS MAINTAINED.

a sufficient length of time until neutralization and pH adjustment is adequate. Oxygen availability to the potentially reactive sulphide minerals is impaired. Oxidation of tailings is impaired.

At present, the chemical/biochemical neutralization process for treatment of acid waters produces a highly reactive, concentrated sludge (Arkay, Katherine E., 1975). This is a severe water pollution problem since it is difficult to dispose of. This method requires constant monitoring, making it a long-term treatment. Economically, it is unfeasible for post-abandonment, since sulphide wastes can produce acids for hundreds of years.

4.3.2 Mitigation of Impoundment Disturbances

4.3.2.1 Construction of Tailings Pond. Initial construction of the tailings area should take advantage of the natural topography if possible, but usually, construction involves excavation and damming. Certain factors must be taken into consideration upon construction. The tailings pond should provide an area of 10 to 25 acres per 100 tons of tailings solids discharged per day (Scott, J.S. and K. Braggs (eds), 1975). While there may be sufficient depth to allow a quiescent sedimentation zone (free of wave disturbance) - especially near the decant outlets - there is a tendency for seepage through the bottom of the pond as pond depth increases. Decant facilities should be as far as possible from pond entry points to facilitate optimum sedimentation conditions.

An impervious embankment is essential to ensure that the amount of contaminated seepage water through the wall is minimized, and that structural stability of the wall is maintained. Natural streams and surface drainage must be diverted around this impoundment to prevent water contamination and minimize volume of water within the impoundment.

Rapid surface run-off of rainwater from the embankment is ensured by covering the embankment surface with an impervious material. This reduces infiltration of water preventing instability of the impounding structure.

4.3.2.2 The Tailings and Water Treatment. Effectiveness of the pond in settling out particulate matter, dissipating chemicals and degrading other toxic substances within the tailings depends on retention time. However, chemicals may be added to accelerate dissipation; flocculants may be added to aid in settling of suspended solids.

The process of acid neutralization with agents such as limestone, lime, sodium carbonate and sodium hydroxide also aid in precipitating heavy metals. Equation 3 outlines the general process, where M^{++} represents the metal cation (Scott, J.S. and K. Bragg (eds), 1975).

$$M^{++} + 2OH^{-} \longrightarrow M(OH)_2 \quad (3)$$

Lime is most commonly used as the pH adjustment reagant.

While the mine is still operating, neutralization of water containing ferric iron is recommended, before it enters the pond. Ferric iron backtriggers the oxidation of pyrite (Scott, J.S. and K. Bragg (eds), 1975). The ferric iron must be bound as ferric hydroxide to prevent acid generation.

Segregation of reactive and non-reactive sulphide tailings will minimize total amount of material necessary to treat. Presence of reactive sulphides in ore or host rock cannot be altered, but that in tailings can be controlled. Low sulphide waste rock can be passed through the mill and spread as the initial cover on the tailings area. The inert portion of the mill tailings collected during regular mill operation could be spread as a final cover.

Highly reactive sulphide wastes must be sealed either chemically or physically. Neutralization of the acidic waste is facilitated by mixing limestone with the last few feet of tailings. The area could then be sealed and revegetated to provide a more aesthetically pleasing view.

Fine-sized tailings particles are usually deficient in nutrients, excessive in salts and lack the normal microbial populations necessary for nitrification. This must be taken into consideration when revegetating an area.

4.4 Intensive Land Use Disturbances - Analysis

Presence of buildings, equipment and machinery are considered intensive land use disturbances.

When a mine is shut down due to adverse economic conditions, the shutdown is normally temporary and all buildings and facilities are left on the property. In contrast, permanent mine closure occurs when ore deposits have been exhausted and normally buildings equipment and machinery are removed.

Six of the seven mine properties studied in this report had unhindered access. Access to the Clinton Creek millsite was controlled however. None of the other properties were fenced off, and buildings were unlocked making them readily accessible (Figures 31 to 36 inclusive). In general, the greater the abandonment period, the less stable the buildings.

Assay labs on both the LaForma and Mount Nansen properties had open access. Hazardous chemicals were found in bottles on shelves and scattered on the floor. The mine sites were left as is upon abandonment. Machinery and equipment were also found at some sites. While these mines may appear isolated, total lack of reclamation upon abandonment is not justified.

4.4.1 Intensive Land Use Disturbances - Environmental Impact. Apart from being aesthetically unappealing, intensive land use disturbances pose a safety hazard to humans and wildlife. Chemicals in the assay labs pose a health hazard. Surface water or precipitation at dump sites could leach toxic materials to surrounding watercourses.

4.4.2 Mitigation of Intensive Land Use Disturbances. All buildings, machinery and equipment should be removed, when a mine is shut down and the mine plant removed, (upon permanent abandonment) as is required in British Columbia (Ministry of Energy, Mines and Petroleum Resources for the Province of British Columbia, 1979). In B.C. all scrap material

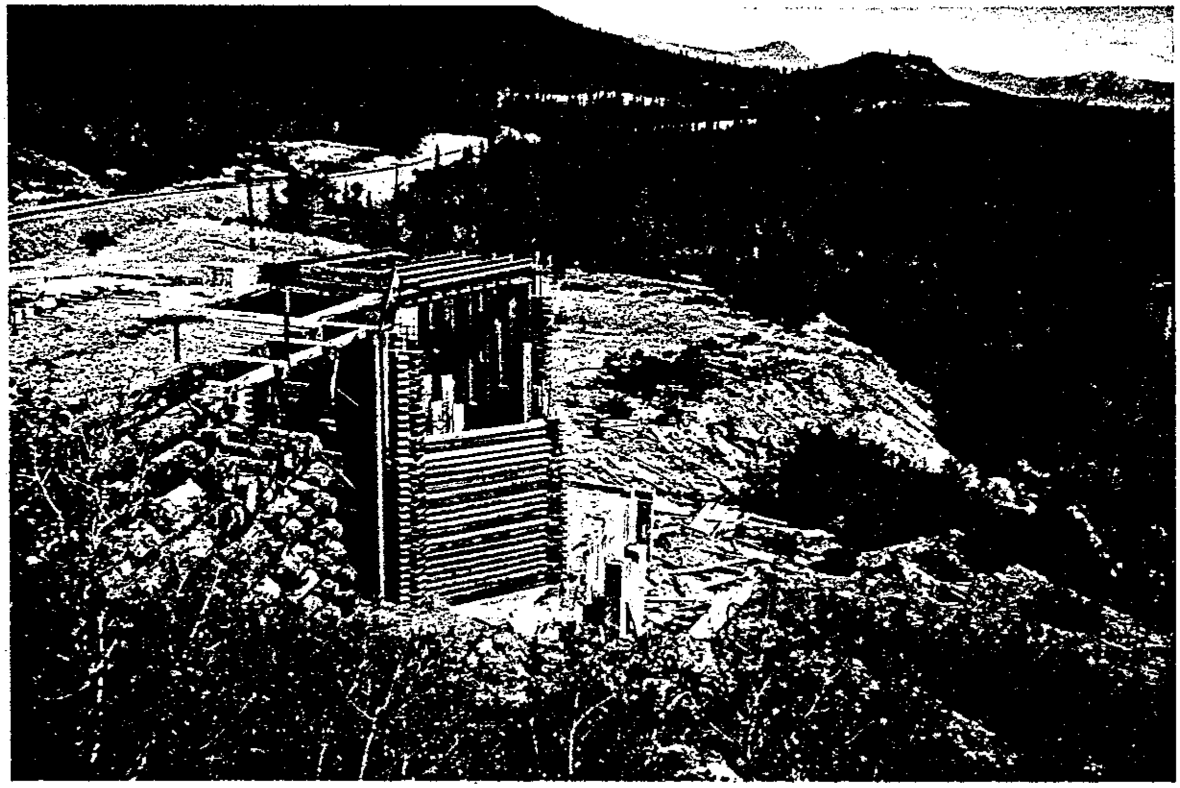

FIGURE 31 ABANDONED VENUS MILL SITE.

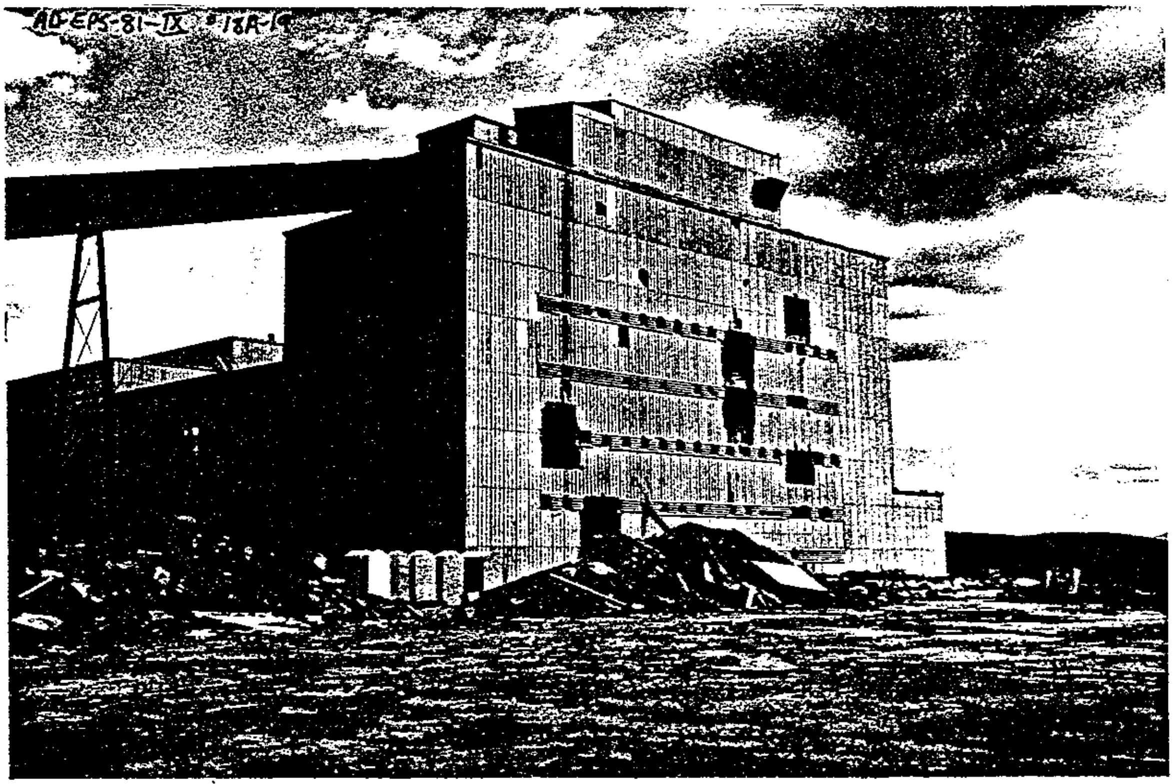

FIGURE 32 CLINTON CREEK MILL SITE. KEY WAS REQUIRED TO ENTER AREA, BUT BUILDING ACCESS IS THEN NOT OBSTRUCTED.

FIGURE 33 ABANDONED MILL SITE ON THE MOUNT NANSEN PROPERTY. NOTE: OPEN ACCESS TO BUILDINGS.

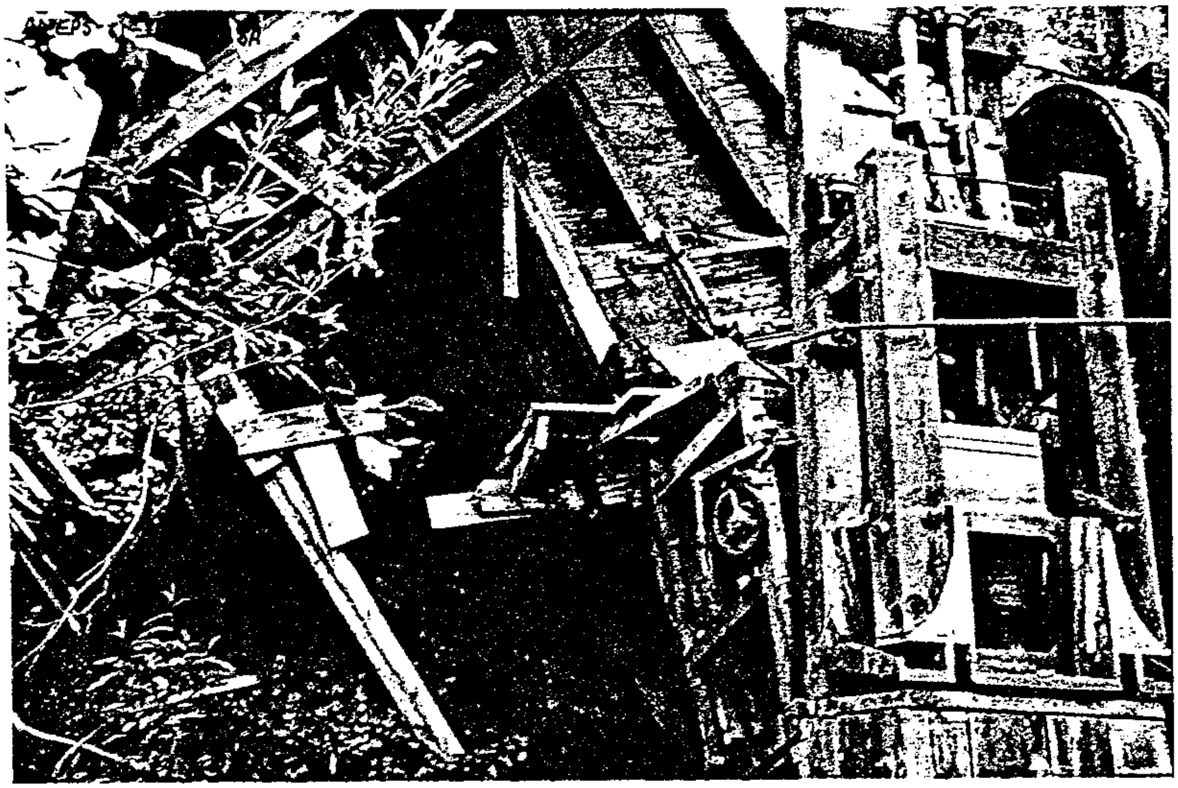

FIGURE 34 ABANDONED WOODEN MILL (ORIGINAL) ON LONE STAR PROPERTY. NOTE: TOTAL COLLAPSE OF THE ROOF.

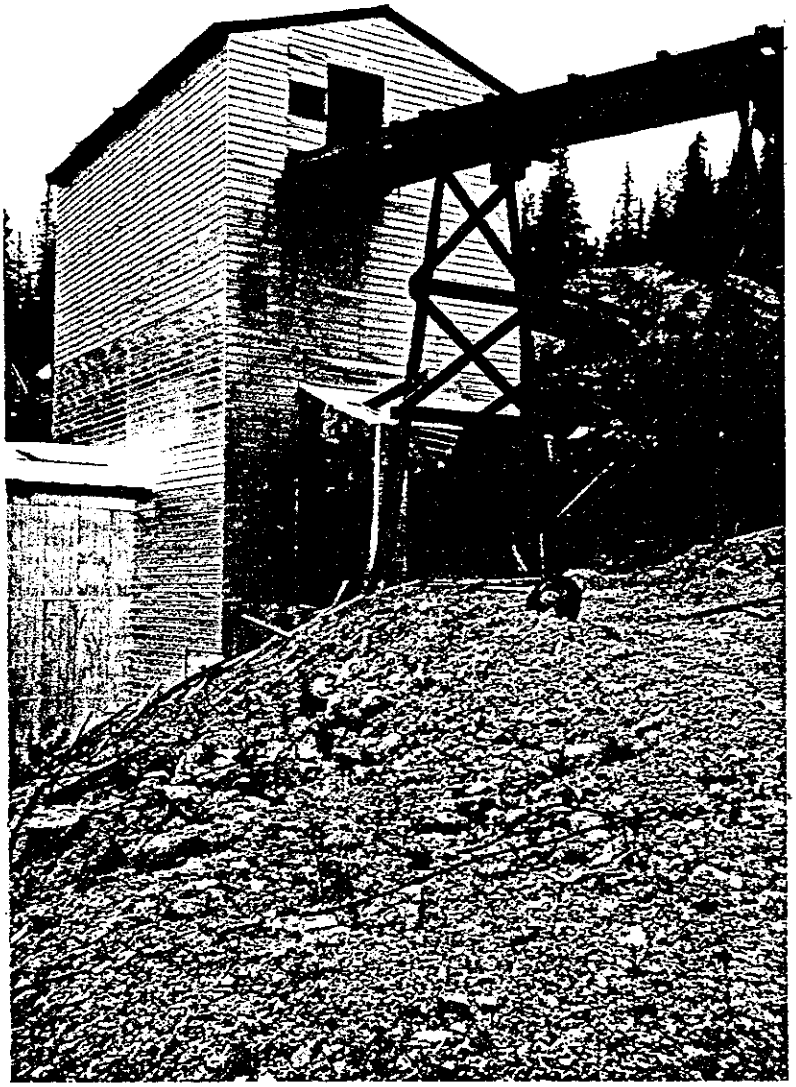

FIGURE 35 ABANDONED 1965 MILL ON LAFORMA PROPERTY. BUILDING ACCESS IS NOT IMPAIRED. NOTE: EXCELLENT CONDITION OF ALUMINUM BUILDING.

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FIGURE 36 OLDEST ABANDONED MILL ON LAFORMA PROPERTY. (1938)

must be disposed of in a manner mutually acceptable to the Ministry of Energy, Mines and Petroleum Resources and the mine operator. Concrete foundations and slabs may be left intact and covered by overburden and revegetated when practical. Clinton Creek is the only site investigated where these measures had been initiated.

Upon temporary abandonment, the area should be fenced off and access rendered only upon authorziation.

Dump areas should be covered with overburden and revegetated, to present a more aesthetically pleasing view.

5 WATER QUALITY AND SEDIMENT ANALYSIS

Water quality and sediment analysis for five of the seven mine sites was performed in an attempt to determine if there was environmental impact from the mine on the surrounding watercourses.

The results of water quality analysis are compared with acceptable concentration limits for raw drinking water supply and concentration limits for healthy aquatic life. Appendix I (Table 3) lists these water quality criteria and their references. The upper concentration limits for healthy aquatic life are usually lower than raw drinking water concentration limits because aquatic life may be more susceptible to harmful effects due to lower tolerance or biomagnification of the substance in the food chain.

Sediment results were compared to values for other Yukon streams subject to placer mining (Mathers et al, 1981) and analysis presented.

5.1 Mount Nansen and Brown McDade Mines

These mines were investigated at the same time, due to their close proximity to one another. Station numbers were set up to include both mine sites.

5.1.1 Water Quality - Mount Nansen and Brown McDade Mines. Water chemistry data is presented in Appendix II (Table 2) and Figure 37, for Mount Nansen and the nearby Brown McDade mine. Station descriptions are given in Table 2.

Conductivity is a measure of ionized salts present in the water. High levels of filterable residues, total alkalinity and total hardness are associated with a high value for conductivity, since all parameters measure the quantity of dissolved solids present.

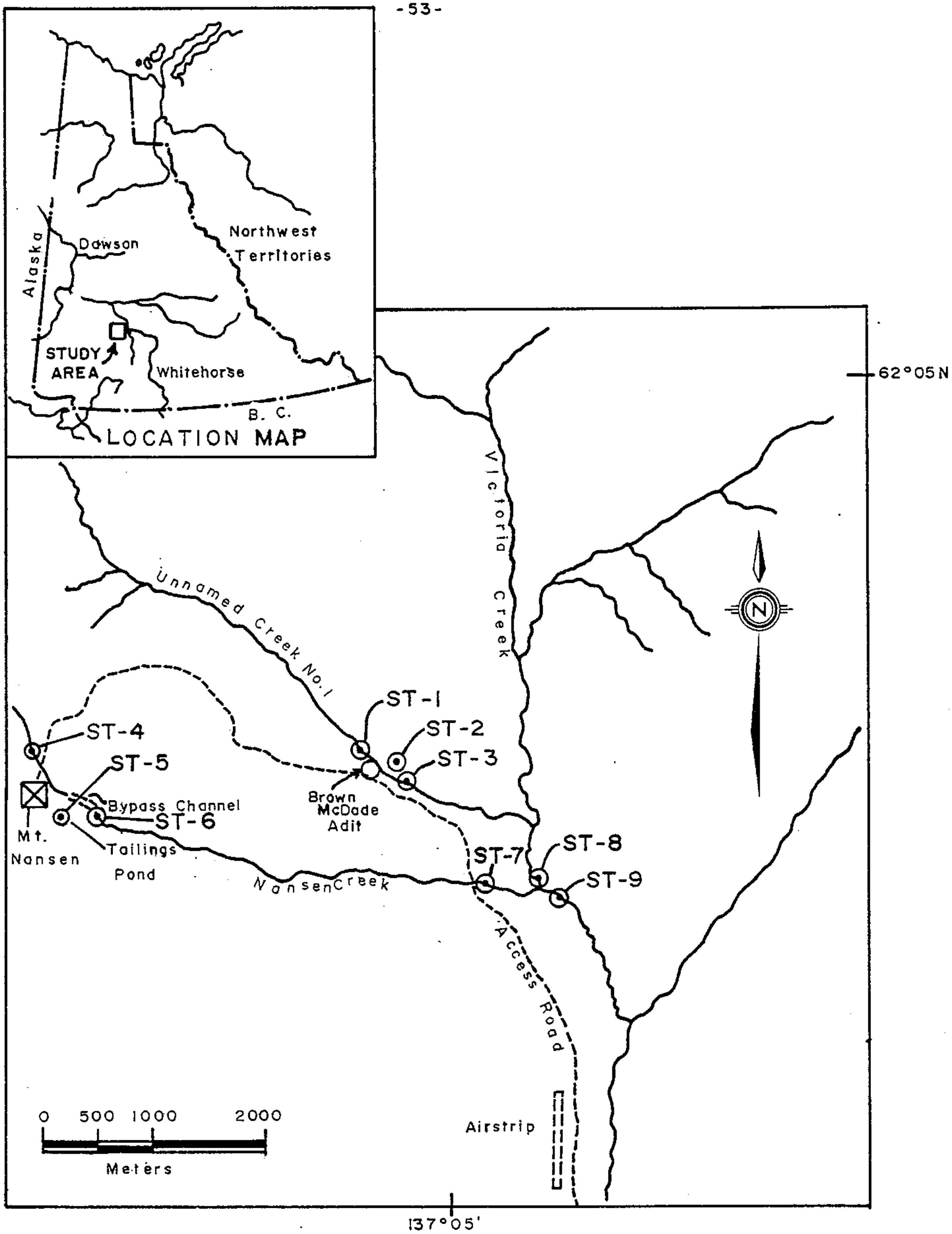

Figure 37 Mount Nansen and Brown McDade Sample Station Locations.

TABLE 2 Station Descriptions for Mount Nansen and Brown McDade Mines

Station	Description of Stations
1	Above Brown McDade adit on Unnamed Creek #1
2	Tailings below Brown McDade adit
3	Below Brown McDade mine on east bank of Unnamed Creek #1
4	Above Mount Nansen tailings and mill on Nansen Creek
5	Tailings area (dry) below Mount Nansen mine. Taken from 2nd of 3 tailings areas
6	Nansen Creek immediately downstream of effluent from third tailings pond
7	Nansen Creek near access road
8	Victoria Creek upstream of confluence with Nansen Creek
9	Victoria Creek downstream of confluence with Nansen Creek

A drastic increase in conductivity between Stations 4 and 6 of the Mount Nansen mine, is seen to continue downstream to as far as Station 7. Mine effluent commonly contains large amounts of dissolved solids. Water quality results immediately downstream of the Mount Nansen waste rock and tailings support this. Results for Stations 6 and 7, indicate conductivity levels in excess of the recommended levels for aquatic life. While the Mount Nansen Creek is being impacted, lower conductivity values at Victoria Creek suggest that dissolved solid concentrations have decreased to safe levels. A breached tailings pond at Mount Nansen may cause an increase of impact on Nansen Creek.

Total hardness is attributed mainly to the presence of calcium and magnesium ions. Stations 6 and 7 of the Mount Nansen mine and Station 3 of the Brown McDade mine contain hard water. Total alkalinity is also higher at Stations 3 and 6, suggesting good buffering capacity. The pit values at stations upstream of the adits (1 and 4) compared to stations downstream of the adits (3, 6 and 7) of both mines support this. Downstream stations have a more basic pH, due to buffering capacity of the water.

During the period of Mount Nansen mill operation (1976), higher than recommended levels of cyanide, arsenic, copper and zinc in the tailings discharge were evident; cyanide levels were seen to persist as far downstream as Station 7. In 1977, the discharge contained lower levels of all metals except zinc. One could assume that quality of the tailings pond discharge had improved (Environmental Protection Service, 1979). Copper and zinc levels from the 1981 sampling, still exceed recommended levels for healthy aquatic life.

Mount Nansen and Unnamed Creek #1 are being impacted downstream of the tailings and waste rock. Extensive rill erosion of the Brown McDade waste rock may lead to increased metal concentrations in Unnamed Creek #1.

Stations 1 and 3 both exceed the cadmium limits for healthy aquatic life. The Brown McDade mine is definitely impacting Unnamed Creek #1. Even though both upstream and downstream stations exceed the upper limit from recommended cadmium levels, the downstream station has levels twice that of the upstream station.

Raw drinking water concentration limits of iron and manganese are exceeded at Station 3, 4 and 6. Manganese levels are above the recommended level for healthy aquatic life at Stations 3 and 4. Iron levels exceed healthy aquatic life levels at Stations 4 and 7. Arsenopyrite and pyrite are among the principal minerals at Mount Nansen (Green, L.H., 1964). This accounts for the high iron and sulphate levels at stations downstream of the mine and tailings. Acid generation from the tailings and/or waste rock may be responsible for the high, sulphate levels at Stations 3, 6 and 7. Mine effluents commonly have high levels of dissolved soilds, as mentioned previously, such as chlorides, nitrates, phosphates or sulphates of sodium, calcium, magnesium, iron and manganese. Station 6 has elevated levels of all these constituents compared to other stations. Good buffering capacity of the water on Mount Nansen Creek and an increased downstream flow rate to dilute absolute concentratons, results in no identifiable impact on Victoria Creek.

Dissolved oxygen levels are too low at all stations for raw drinking water consumption. Only Station 3 and 4 contain less than the lower limit ($\geq$54% saturation) required for healthy aquatic life.

5.1.2 Sediment Analysis - Mount Nansen and Brown McDade Mines.

Appendix III (Table 1) and Figure 38 present the sediment data. Compared to other Yukon streams (Mathers et al, 1981), sediment samples at Stations 2, 3, 5 and 6 show elevated lead and zinc levels. Copper levels exceed Mathers data at Stations 2 and 3 of the Brown McDade mine by factors of approximately 4 and 15 respectively. Cadmium is elevated at Stations 3, 5 and 6 by factors of about 14, 15 and 7 compared to other Yukon streams.

Results reflect those obtained for water quality, with elevated metal concentrations occurring for both sediment and water at any one station. The tailings of both mines are definitely impacting Nansen Creek and Unnamed Creek #1.

Higher sediment mercury levels in the tailings at the Brown McDade mine (Station 2) compared to the downstream station suggest possible presence of mercury in the mine's ore body. Concentrations at both stations are only slightly higher than other Yukon stream sediments though.

5.2 Clinton Creek Mine

5.2.1 Water Quality - Clinton Creek Mine. Station locations and descriptions are presented in Figure 38 and Table 3 respectively. Water quality results are presented in Appendix II (Table 2).

Conductivity is higher than recommended levels for healthy aquatic life at Stations 1, 2, 4 and 6. A lab value of 995 umhos/cm recorded for Station 4 for conductivity is consistent with the evelated values for filterable - residues, calcium, magnesium, nitrate, sulphate, phosphate and chlorine, indicating the presence of high dissolved salts in the water. Upstream of Station 3, dilution by Hudgeon Lake may decrease the concentrations of these metals. High levels of magnesium at Stations 2 and 4 are indicative of the brucite (MgO, H_2O) and magnesium carbonate in the ore body (Landucci, J., 1978). These levels are not endangering aquatic life though. Similarly manganese levels are elevated at Stations 2 and 4. Thus the tailings pile on Wolverine Creek and waste rock pile Clinton Creek are affecting water quality. As mentioned previously, both piles are still unstable and downslope movement of them into the creeks is still occurring.

High sulphate levels at Station 4 suggest that mine waste rock acid production is impacting Clinton Creek, however a good buffering capacity of water at Station 4 (indicated by very hard water value of 543 mg/l) minimizes the impact. Sulphate levels have descreased again at Station 6 - suggesting no identifiable impact on Forty Mile River.

Dissolved oxygen levels are lower than recommended levels for drinking water (100% saturation) at all stations. The 54% recommended saturation level for aquatic life is not met at Stations 1 and 5.

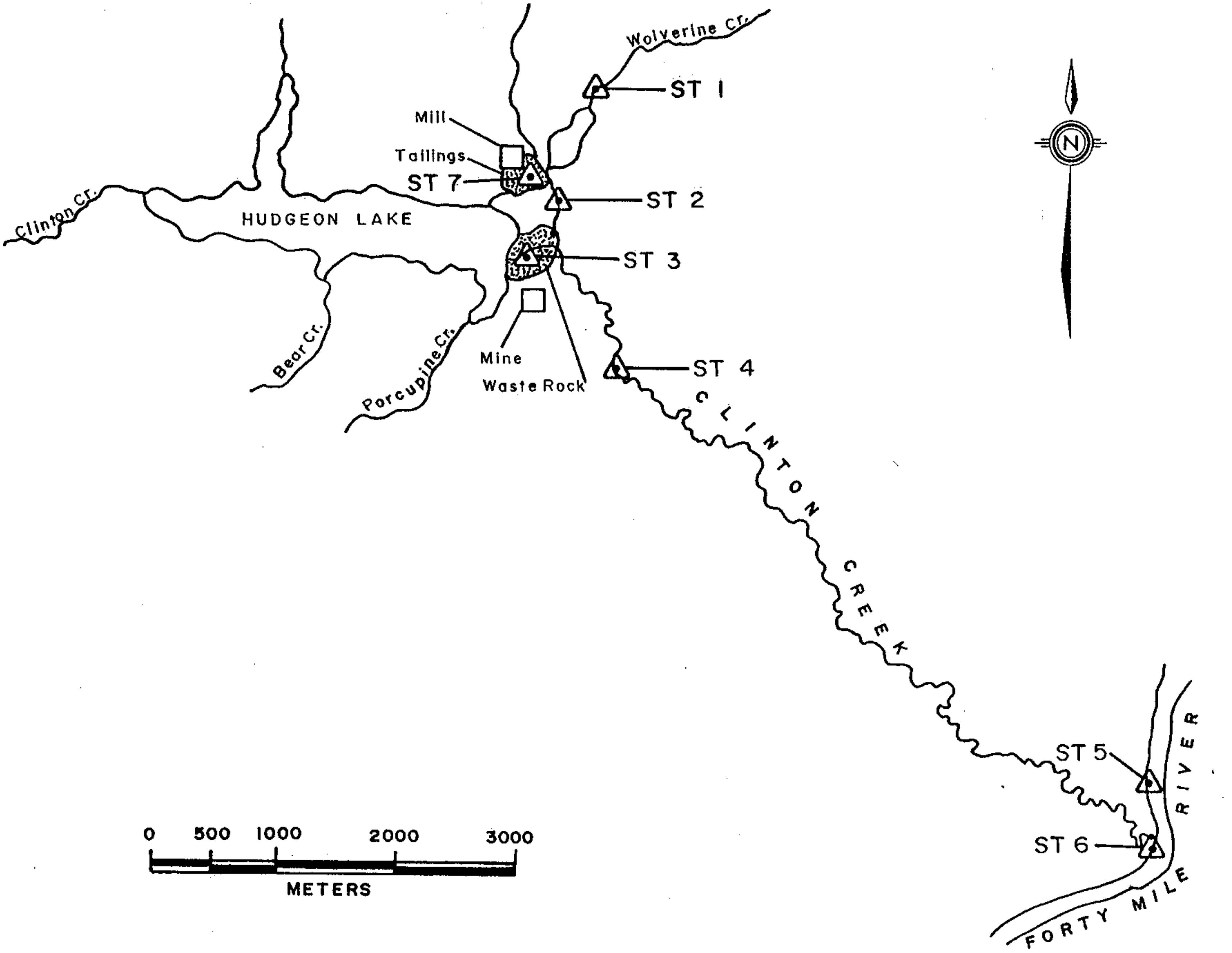

FIGURE 38 CLINTON CREEK SAMPLE STATION LOCATIONS

TABLE 3 Station Descriptions for Clinton Creek Mine

Station	Description of Stations
1	Upstream of mine pit, waste rock and tailings on Wolverine Creek
2	Downstream of mill tailings on Wolverine Creek
3	Hudgeon Lake runoff which feeds into Clinton Creeks Water sample taken from tail end of 1 of 3 culvert draining from Hudgeon Lake into Clinton Creek
4	Downstream of mine waste rock and mill tailings on Clinton Creek
5	On Forty Mile River downstream of its confluence with Clinton Creek
6	On Forty Mile River upstream of its confluence with Clinton Creek
7	Dry tailings sample

5.2.2 Sediment Analysis - Clinton Creek Mine. Sediment chemistry data is presented in Appendix III (Table 2). Barium, chromium and nickel levels are elevated in comparison to other Yukon streams, (Mathers et al, 1981) at Stations 2 and 5. Extremely elevated chromium levels in the dry tailings sample (Station 7) accounts for the elevated levels at the downstream Station 2. Nickel levels are also high in the dry tailings. Extremely high magnesium levels (275,000 mg/kg) at Station 7 exceed other Yukon stream sediment concentrations (Mathers et al, 1981) by a factor of 20. Stations 2 and 4 are being impacted by the brucite and magnesium carbonate in the main ore body, (Htoon, M., 1975) showing high magnesium levels. Magnesium levels at Station 3 decrease, due to dilution of Hudgeon Lake. Impact decreases more from Station 4 on Clinton Creek to Forty Mile River; there is no impact of magnesium on Forty Mile River.

Calcium levels are greatest at Station 3, due to the presence of limestone argillite and/or magnesium carbonate in the mine waste rock (Htoon, M., 1975).

It can be noted that low levels of phosphorus and potassium in the dry tailings sample (Station 7) suggest poor conditions for revegetation of the area. This is supported by Figures 13 and 14.

5.3 LaForma Mine

5.3.1 Water Quality - LaForma. Station locations and descriptions are presented in Figure 39 and Table 4.

Water quality results are listed in Appendix II (Table 3). All stations had hard water exceeding the recommended levels for drinking water.

Stations 1 and 3 had elevated concentrations of arsenic, copper and zinc; Station 3 had elevated levels of aluminum and iron. Disseminated arsenopyrite is abundant locally (Sinclair, W.D. et al, 1975) explaining elevated arsenic levels. Elevated copper levels can be attributed to the weak copper mineralization of the area (Sinclair, W.D. et al 1975). Iron oxides and manganese staining are locally abundant along fractures. Stations 1 and 3 also exceed the safe drinking water levels for arsenic. Recommended drinking water levels for iron are exceeded at Sation 3. Manganese concentrations at Stations 1, 3 and 4 are above safe levels for drinking water.

Elevated metal concentrations in Unnamed Creek #2 suggest that the mine's ore body is impacting Unnamed Creek #2. Metal concentrations in Seymour Creek are below the recommended limits for drinking water and aquatic life. It has not been impacted.

5.3.2 Sediment Analysis - La Forma Results for sediment samples are presented in Appendix III (Table 3). The tailings samples do not exhibit concentrations of any metals when compared to other Yukon streams. The tailings do not appear to be impacting Unnamed Creek #2.

5.4 Lone Star Mine

5.4.1 Water Quality - Lone Star Mine Station locations and descriptions are supplied in Figure 40 and Table. 5

Water quality is presented in Appendix II (Table 4).

The general vicinity of Station 1 was marshy. The water sample reflected high amounts of organic matter in its high values for filterable residue, and conductivity. Dissolved oxygen saturation was

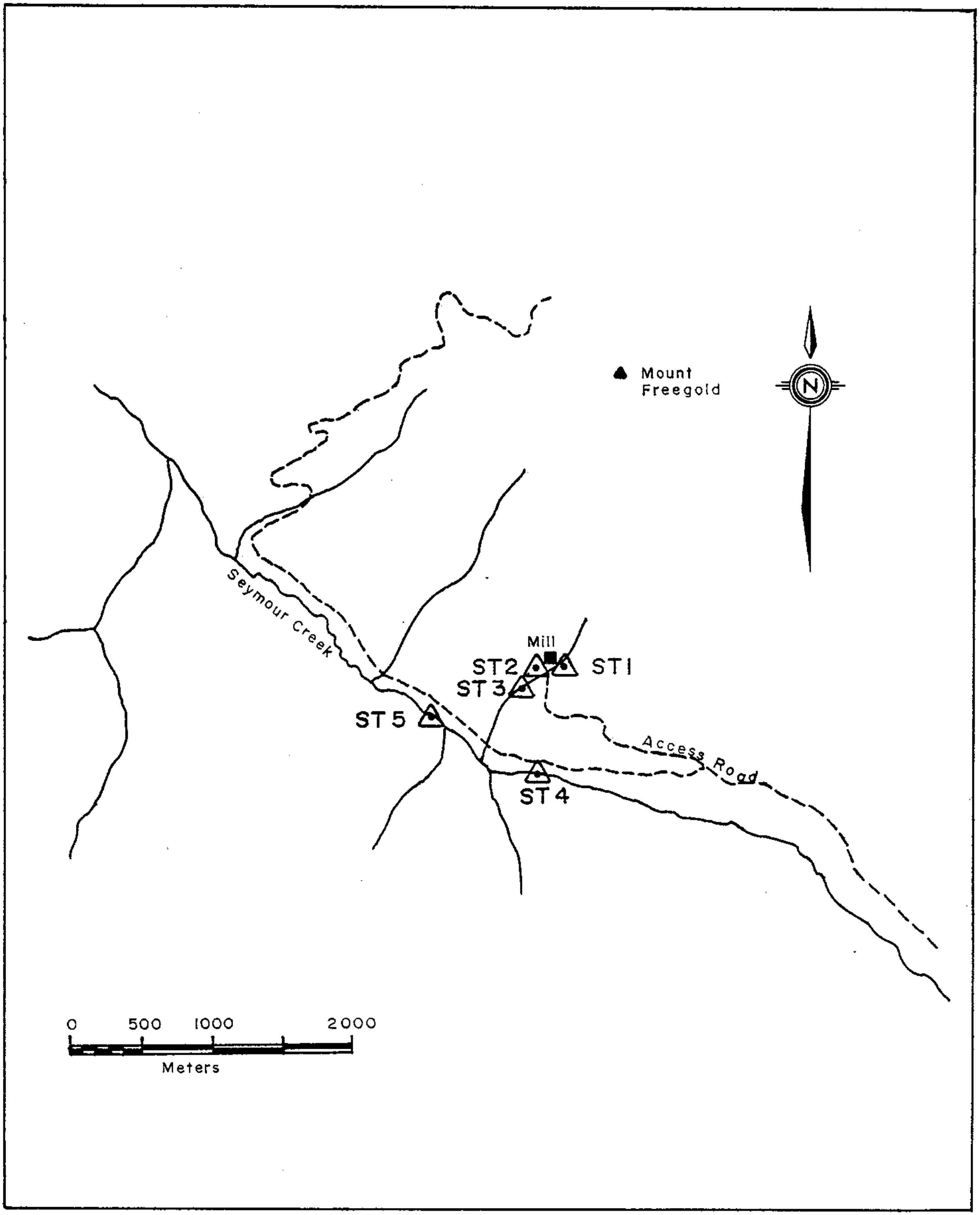

Figure 39 La Forma Sample Station Locations

TABLE 4 Station Descriptions for La Forma Mine

Sample #	Description
1	Excavated storage reservoir for camp water supply located at mouth of Adit 3 on South slope of Mount Freegold.
2	Bottom of dry tailings impoundment from 1965 mill.
3	Intermittent Unnamed Creek No. 2 draining storage reservoir.
4	On Seymour Creek, 0.5 km upstream of its confluence with Unnamed Creek No. 2.
5	On Seymour Creek, 0.5 km downstream of its confluence with Unnamed Creek No. 2.

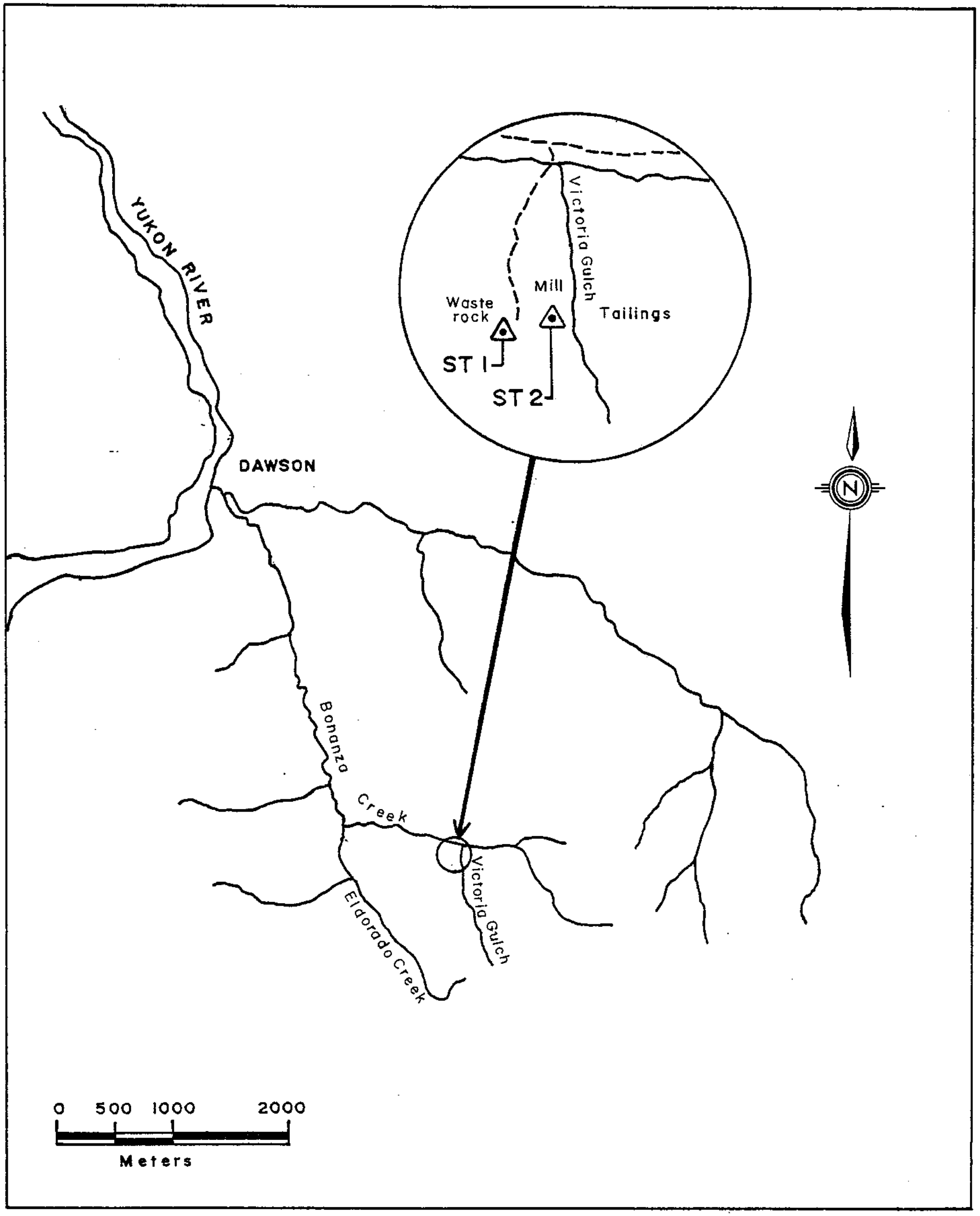

Figure 40 Lone Star Mine Sample Station Locations

TABLE 5 Station Descriptions for Lone Star Mine

Station	Description
1	Groundwater draining from Adit
2	Dry tailings sample taken from tailings area.

below recommended levels for drinking water supply but would support healthy aquatic life. Metal concentrations were below recommended levels for safe drinking water and existence of healthy aquatic life.

5.4.2 Sediment Analysis - Lone Star Appendix III (Table 4) presents the analysis of the tailings sediment samples. Mineralization consisting of siderite, galena and lead carbonate (Gleeson, C.F., 1970) explains the elevated lead concentration.

6 Summary and Recommendations

There is a growing concern for long-term, environmental problems occurring after abandonment of hard-rock mines in the Yukon. Recognition of these problems in the past few decades has led to discussion among regulatory agencies regarding a need for establishment of reclamation guidelines.

Prior to operation of a mine, an environmental impact assessment statement should be prepared. Mitigative measures should be identified and implemented during the operation phase to reduce environmental problems on abandonment. This could reduce the cost of rehabilitation upon abandonment. Adequate funds should also be set aside prior to the operation stage to ensure that the operator does rehabilitate the area. In many cases, inclusion of mitigative measures can reduce post-abandonment pollution problems.

Of the seven mines investigated, an attempt to obstruct public entrance at only one site was evident. All others were readily accessible. Adits were left open at all sites. Machinery and equipment remained on site of some properties.

Tailings ponds at some sites were not left maintenance-free. Breached tailings, severed pipes connecting ponds and inadequate decant structures were evident. Unstable waste rock embankments, with steep slopes were abandoned with no attempt at recontouring or revegetation.

While temporary abandonment of mines is common in the Yukon Territory, reclamation of these mines is necessary. Minimizing environmental impact of the mining industry will aid to preserve the quality of the environment.

6.1 Reclamation

Adits:

1. Upon temporary abandonment, adit openings should be fenced off, impeding passage of humans/wildlife.
2. Water drainage should be diverted from adits exposing a potentially reactive sulphide ore body face.

Open Pits:

1. Open pits should be backfilled if possible (with non-reactive sulphide waste material). Economically, fencing off hazardous areas of the pit may be more feasible. In areas where steep escarpments occur naturally in the topography, fencing could be employed.
2. Recontouring and revegetation of unstable pit walls should be undertaken. The area must be in a maintenance-free condition.

Waste Rock Piles:

1. Recontouring of waste rock piles exceeding the angle of repose should be carried out. Overburden should be spread and revegetation employed. Sulphide reactive wastes should be sealed initially. The area must be maintenance-free.
2. Diversion of natural water courses and ground water around potentially reactive sulphide wastes is essential.

Tailings Ponds:

1. All impoundment structures (berms, embankments, etc.) should be maintenance-free upon abandonment. The area should be checked regularly to ensure this.

2. All natural watercourses and groundwater should be diverted around the impoundment area.
3. Where necessary, a permanent spillway should be provided on, or adjacent to the tailings dam to provide for excessive run-off water.
4. If practical, the tailings area should be revegetated to a maintenance-free condition . Sealing of the surface and/or spreading of overburden may be necessary if the tailings contain wastes that are toxic to plants.

Buildings, Machinery & Equipement:

1. Upon temporary abandonment, all buildings, machinery and equipment shall be confined to a restricted fenced area prohibiting passage to humans/wildlife.
2. Permanent abandonment would require that buildings be torn down if no alternate use for them could be established. Foundations and slabs could be left intact and covered with overburden. All machinery and equipment would be removed from the area.
3. All chemicals should be removed upon abandonment.

Waste Dumps:

1. Waste dumps should be recontoured to an angle allowing establishment of vegetation. Overburden application would probably be necessary. The area must be maintenance-free.
2. Natural water courses and groundwater must be diverted around dump area.

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APPENDICES

APPENDIX I

SAMPLE 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	0.0050 mg/l	Single 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 Organic Carbon (TOC)	1.0 mg/l	Single samples collected in 100 ml glass jars. No preservative. Stored at 4°C.	Carbon Infra-red Analyzer	016
Total Inorganic Carbon (TIC)	1.0 mg/l	Same sample as TOC	Carbon Infra-red Analyzer	016
Total Phosphate T PO_4-P	0.0050 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	0.0050 mg/l	Same sample as NH_3.	Diazotization-Colorimetric-Automated	070
Nitrate NO_3-N	0.010 mg/l	Same sample as NH_3.	Cadmium Copper Reduction Colorimetric Automated	072
Sulphate SO_4	1.00 mg/l	Same sample as NH_3.	Barium Chloranilate -UV Spectrophotometric	122
Chloride Cl	0.50 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
Silicon Total Si	0.50 mg/l	Same sample as NH_3.	Ascorbic Acid Reduction - Colorimetric	118
Mercury Total Hg	0.00020 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	0.050			
As	0.075			
Ba	0.0015			
Be	0.0010			
Ca	0.050			
Cd	0.0040			
Co	0.0075			
Cr	0.0075			
Cu	0.0050			
Fe	0.0050			
Mg	0.10			
Mn	0.0010			
Mo	0.015			
Na	0.50			
Ni	0.040			
Pb	0.040			
Sb	0.040			
Se	0.075			
Sn	0.10			
Sr	0.0020			
Ti	0.0040			
V	0.020			
Zn	0.0050			

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]
Cd	0.0010	Same sample as metals.	Graphite Atomic Absorption Flameless Technique (AAS)	Atomic Absorption Jerrel-Ash 850 Manual
Cu	0.0010	Same sample as metals.		
Pb	0.0010	Same sample as metals.		
Zn	0.0010	Same sample as metals.		
Ag	0.030 mg/l	Same sample as metals.	Flame Atomic Absorption Spectrophotometry	210 290
K	0.010 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 $CaCO_3$	

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[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 Parameters	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 (-19°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 EPS Lab
[2]Sb	Same as other metals.	Hydride Generation ICAP	
[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 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 3 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/)				
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 3 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).

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APPENDIX I TABLE 3 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)

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APPENDIX II

WATER QUALITY DATA

APPENDIX II TABLE 1 MOUNT NANSEN & BROWN MCDADE - WATER QUALITY, June 9, 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)	COLOUR (colour units)	TURBIDITY (FTU)
1	0.0047(e)	12	7.12	75.1	7.3	7.4	58	82	50	<1.0
3	0.0059(e)	3	3.92	32.9	7.1	7.5	160	449	20	<1.0
4	0.0010(e)	4	<1.0	<9.0	6.9	6.5	140	189	>100	37
6	0.0010(e)	14	8.92	99.3	7.7	8.0	900	1120	20	2.6
7	0.0189(e)	7	8.40	78.0	7.1	7.7	270	530	60	8.9
8	0.3149(e)	8	9.05	86.0	7.3	8.0	100	166	10	<1.0
9		6	6.40	57.7	7.1	8.0	100	159	5	<1.0

(e) very rough estimate

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	<5.0	89	26.0	34.3	0.0098	<0.0050	0.0131	0.0230	13.2	<0.020	0.70
3	8.0	323	85.7	216	<0.0050	<0.0050	0.319	0.0235	128	<0.020	0.64
4	85	153	34.0	76.9	0.041	<0.0050	<0.0100	0.0230	51.8	<0.020	2.81
6	11	931	114	592	0.013	<0.0050	0.223	0.104	489	<0.020	0.99
7	18	396	66.6	257	0.013	<0.0050	0.0792	0.0340	188	<0.020	1.02
8	<5.0	109	71.4	80	<0.0050	<0.0050	0.0730	0.0135	13.9	<0.020	<0.50
9	<5.0	112	71.4	80	<0.0050	<0.0050	0.0697	0.0111	15.0	<0.020	<0.50

APPENDIX II TABLE 1 MOUNT NANSEN & BROWN MCDADE - WATER QUALITY, June 9, 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	<0.030	0.064	<0.075	0.0499	<0.0010	10.3	0.0040	<0.0075	<0.0075	0.0054	0.146	<0.00020	0.280
3	<0.030	<0.050	<0.075	0.0219	<0.0010	66.6	0.0100	<0.0075	<0.0075	0.0398	0.447	<0.00020	0.782
4	<0.030	0.204	0.714	0.139	<0.0010	22.8	<0.0010	<0.0075	<0.0075	0.0014	29.1	<0.00020	2.00
6	<0.030	0.063	<0.075	0.0465	<0.0010	151	<0.0010	<0.0075	<0.0075	0.0058	0.856	<0.00020	3.72
7	<0.030	<0.050	<0.075	0.0531	<0.0010	67.5	<0.0010	<0.0075	<0.0075	<0.0019	1.07	<0.00020	1.74
8	<0.030	<0.050	<0.075	0.0569	<0.0010	22.0	<0.0010	<0.0075	<0.0075	0.0015	0.0334	<0.00020	0.774
9	<0.030	<0.050	<0.075	0.0546	<0.0010	22.0	<0.0010	<0.0075	<0.0075	0.0014	0.0226	<0.00020	0.633

STATION NUMBER	Mg mg/l	Mn mg/l	Mo mg/l	Na	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	2.09	0.0184	<0.015	2.23	<0.040	0.0400	<0.040	<0.075	6.05	<0.10	0.0693	<0.0040	<0.020	0.0543
3	12.1	1.68	<0.015	3.45	<0.040	0.0102	<0.040	<0.075	6.86	<0.10	0.315	<0.0040	<0.020	0.717
4	4.85	3.59	<0.015	3.47	<0.040	0.0020	<0.040	<0.075	5.89	<0.10	0.103	0.0106	<0.020	0.013
6	52.3	0.467	<0.015	12.1	<0.040	0.0074	<0.040	<0.075	4.00	<0.10	0.398	<0.0040	<0.020	0.231
7	21.6	0.0028	<0.015	5.43	<0.040	<0.0010	<0.040	<0.075	5.09	<0.10	0.197	<0.0040	<0.020	0.0091
8	6.11	0.0289	<0.015	2.06	<0.040	<0.0010	<0.040	<0.075	5.11	<0.10	0.214	<0.0040	<0.020	0.0018
9	6.07	0.0280	<0.015	2.16	<0.040	<0.0010	<0.040	<0.075	5.06	<0.10	0.209	<0.0040	<0.020	0.0029

APPENDIX II TABLE 2 CLINTON CREEK - WATER QUALITY, June 23, 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)	COLOUR (colour units)	TURBIDITY (FTU)
1		6	4.6	38.7	7.4	7.9	409	688	65	<1.0
2		7	7.6	65.5	7.7	8.9	352	604	45	<1.0
3		20	6.9	56.6	6.8	7.5	175	216	>100	<1.0
4		12	8.0	66.7	7.4	7.8	750	995	55	<1.0
5		16	4.2	36.5	5.2	7.6	145	172	70	<1.0
6		12	6.9	62.5	6.8	7.7	393	618	55	<1.0

(e) very rough estimate

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	<5.0	536	121	358	0.0100	<0.0050	<0.010	0.0105	245	<0.030	0.94
2	<5.0	432	189	326	0.0230	0.0114	0.287	0.0222	150	<0.030	1.30
3	<5.0	200	54.9	105	0.0130	<0.0050	<0.010	0.0337	48.7	<0.030	1.40
4	<5.0	784	183	543	0.114	<0.0050	0.135	0.0148	363	<0.030	3.01
5	<5.0	140	56.5	86.1	0.0097	<0.0050	0.012	0.0083	26.8	<0.030	1.32
6	<5.0	397	141	362	0.0088	<0.0050	0.039	0.0105	184	<0.030	2.06

APPENDIX II TABLE 2 CLINTON CREEK - WATER QUALITY, June 23, 1982 (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	<0.030	0.094	<0.00050	0.0802	<0.0010	69.7	<0.0010	<0.0075	<0.0075	0.0088	0.196	<0.00020	0.672
2	<0.030	<0.050	0.00306	<0.0699	<0.0010	25.5	<0.0010	<0.0075	<0.0075	0.0049	0.0516	<0.00020	0.774
3	<0.030	0.107	<0.00050	0.0329	<0.0010	25.4	<0.0010	<0.0075	<0.0075	0.0093	0.228	<0.00020	0.412
4	<0.030	<0.050	0.00071	0.0536	<0.0010	96.3	<0.0010	<0.0075	<0.0075	0.0050	0.153	<0.00020	1.13
5	<0.030	0.091	<0.00050	0.0380	<0.0010	21.8	<0.0010	<0.0075	<0.0075	0.0049	0.188	<0.00020	0.876
6	<0.030	<0.050	<0.00050	0.0621	<0.0010	64.5	<0.0010	<0.0075	<0.0075	0.0115	0.0567	<0.00020	0.985

STATION NUMBER	Mg mg/l	Mn mg/l	Mo mg/l	Na	Ni mg/l	Pb mg/l	Sb mg/l	Se mg/l	Si mg/l	Sn mg/l	Sr mg/l	Tl mg/l	V mg/l	Zn mg/l
1	44.8	0.0056	<0.015	3.11	<0.040	0.0011	<0.040	<0.075	6.14	<0.10	0.364	<0.0040	<0.020	0.0200
2	63.7	0.0972	<0.015	2.61	<0.040	<0.0010	<0.040	<0.075	3.25	<0.10	0.167	<0.0040	<0.020	0.0076
3	10.2	0.0104	<0.015	1.4	<0.040	0.0014	<0.040	<0.075	3.61	<0.10	0.123	<0.0040	<0.020	0.0180
4	73.6	0.112	<0.015	4.84	0.056	<0.0010	<0.040	<0.075	4.42	<0.10	0.619	<0.0040	<0.020	0.0094
5	7.70	0.0080	<0.015	3.55	<0.040	<0.0010	<0.040	<0.075	4.40	<0.10	0.126	<0.0040	<0.020	0.0126
6	48.9	0.0109	<0.015	4.2	<0.040	<0.0010	<0.040	<0.075	4.49	<0.10	0.402	<0.0040	<0.020	0.0277

APPENDIX II TABLE 3 LAFORMA - WATER QUALITY, June 11, 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)	COLOUR (colour units)	TURBIDITY (FTU)
1	--	7	-	-	-	7.9	270	457	5	3.1
3	<0.010(e)	9	-	-	-	8.3	320	483	5	28
4	0.061(e)	6	-	-	-	8.3	200	350	10	<1.0
5	0.142(2)	6	-	-	-	8.1	180	332	20	2.7

(e) Very rough estimate

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	9.0	300	130	220	0.0260	<0.0050	0.072	0.0076	101	<0.03	0.83
3	85	322	133	230	0.0730	<0.0050	<0.010	0.0106	107	<0.03	1.43
4	<5.0	215	176	168	0.0059	<0.0050	0.062	0.0064	13.0	<0.03	0.77
5	24	203	166	160	0.0210	<0.0050	0.078	0.0074	9.6	<0.03	0.77

APPENDIX II TABLE 3 LAFORMA - WATER QUALITY, June 11, 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	<0.030	0.078	0.544	0.0262	<0.0010	69.3	<0.0010	<0.0075	<0.0075	0.0124	0.165	<0.00020	0.868
3	<0.030	1.24	0.587	0.0863	<0.0010	73.6	<0.0010	<0.0075	<0.0075	0.0260	2.25	<0.00020	1.27
4	<0.030	<0.050	<0.075	0.161	<0.0010	38.8	<0.0010	<0.0075	<0.0075	<0.0010	0.0136	<0.00020	0.876
5	<0.030	0.138	<0.075	0.153	<0.0010	33.3	<0.0010	<0.0075	<0.0075	0.0020	0.193	<0.00020	0.876

STATION NUMBER	Mg mg/l	Mn mg/l	Mo mg/l	Na	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	11.4	0.113	0.059	5.84	<0.040	<0.0010	<0.040	<0.075	5.74	<0.10	0.871	<0.0040	<0.020	0.0956
3	11.3	0.191	0.062	5.93	<0.040	0.0079	<0.040	<0.075	5.84	<0.10	0.845	0.0126	<0.020	0.0350
4	17.3	0.368	<0.015	9.60	<0.040	<0.0010	<0.040	<0.075	4.83	<0.10	0.470	<0.0040	<0.020	0.0014
5	18.7	0.0175	<0.015	8.05	<0.040	0.0102	<0.040	<0.075	4.88	<0.10	0.469	0.0047	<0.020	0.0027

APPENDIX II TABLE 4 LONE STAR - WATER QUALITY, June 23, 1982

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)	COLOUR (colour units)	TURBIDITY (FTU)
1	0.0762(e)	5	7.0	61.4	6.1	7.8	---	523	<5.0	<1.0

(e) very rough estimate

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	<5.0	354	96.7	250	0.0056	<0.0050	0.013	0.0082	163	<0.030	0.62

APPENDIX II TABLE 4 LONE STAR - WATER QUALITY, June 23, 1982 (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	<0.030	0.054	<0.00050	0.0171	<0.0010	74.7	<0.0010	<0.0075	<0.0075	0.0069	0.116	<0.00020	0.860

STATION NUMBER	Mg mg/l	Mn mg/l	Mo mg/l	Na	Ni mg/l	Pb mg/l	Sb mg/l	Se mg/l	Si mg/l	Sn mg/l	Sr mg/l	Tl mg/l	V mg/l	Zn mg/l
1	13.7	0.0791	<0.015	2.21	<0.040	0.0011	<0.040	<0.075	6.39	<0.10	0.431	<0.0040	<0.020	0.0588

APPENDIX III

SEDIMENT DATA

APPENDIX III TABLE 1 MOUNT NANSEN AND BROWN MCDADE - SEDIMENT CHEMISTRY DATA, June 9, 1981
(all concentrations given in mg/kg dryweight unless otherwise noted)

STATION	CN w/w*	Ag	Al	As	Ba	Be	Ca	Cd	Cr	Cu	Fe	Hg	K	Mg
1-1	<0.4	<4.94	17600	-	353.0	0.478	7390	3.37	27.9	32.0	31800	<0.182	1660	3750
1-2		<4.84	16900	84.3	359.0	0.402	7620	3.89	21.8	30.9	33000	0.229	1420	3450
1-3		<4.83	16500	66.8	274.0	0.450	6780	2.45	21.7	27.6	27600	0.167	1420	3520
2-1	<0.25	60.5	11700	2130	248.0	0.370	14700	9.39	6.43	430	90700	0.698	5160	898
3-1	<0.2	125	9370	2760	369.0	0.391	4850	51.1	17.4	1700	177000	0.547	3140	1290
3-2		97.2	8520	2040	305.0	0.374	4260	36.1	9.59	1220	148000	0.504	3000	1290
3-3		180	11000	3130	418.0	0.459	4860	66.2	29.5	1840	174000	0.679	3350	1340
4-1		<4.93	17300	463.0	311.0	0.386	6840	0.950	15.6	31.2	66400	<0.196	2480	6090
4-2		<4.91	25200	400.0	462.0	0.792	10000	0.971	23.9	49.5	85100	0.260	3150	8140
4-3		<4.89	14000	319.0	236.0	0.301	5990	0.570	13.3	22.5	50700	0.167	2050	4990
5-1	1.0	53.6	2730	6250	163.0	<0.165	4400	55.3	4.85	264.0	51700	0.218	1520	1120
6-1	0.44	20.7	17700	1380	240.0	0.385	10300	30.7	30.9	190.0	46600	0.206	2470	4770
6-2		16.5	16300	1410	218.0	0.354	9210	25.2	33.1	145.0	45700	<0.179	2350	4320
6-3		16.2	15900	-	196.0	0.358	8190	19.9	28.8	131.0	41500	<0.185	2180	4450
8-1	<0.6	<4.94	11700	-	147.0	0.353	6890	<0.580	31.9	22.4	31800	<0.196	1170	3190
8-2		<4.90	10200	8.84	118.0	0.497	6900	<0.570	41.2	23.3	44000	<0.196	1300	2890
8-3		<4.90	11200	18.5	141.0	0.416	6690	<0.580	39.6	25.6	35100	<0.189	1230	3090
9-1	<0.70	<4.85	10400	44.7	138.0	1.10	7270	0.620	39.0	25.8	41700	<0.161	1290	3030
9-2		<4.87	10700	23.9	126.0	0.641	7230	<0.570	40.6	51.8	36800	<0.156	1230	3110
9-3		<4.83	9620	-	111.0	0.394	6390	0.680	31.4	27.3	37400	<0.189	1220	2840

*w/w Means mg/kg wet weight total sample. All other measurements in this table are given in mg/kg dry weight for the portion passing a 150 um sieve.

APPENDIX III TABLE 1 MOUNT NANSEN AND BROWN MCDADE - SEDIMENT CHEMISTRY DATA, JUNE 9, 1981 (continued)
(all concentrations given in mg/kg dryweight unless otherwise noted)

STATION	Mn	Mo	Na	Ni	P	Pb	Sb*	Se*	Si	Sn	Sr	Ti	V	Zn
1-1	1960	<2.47	355.0	10.8	812.0	118.0	1.85	<0.820	3880	26.4	62.5	1170	59.8	338.0
1-2	2090	<2.42	274.0	7.70	874.0	129.0	2.19	<0.785	4460	<16.2	64.3	795.0	51.8	358.0
1-3	1400	<2.41	329.0	<6.43	744.0	93.8	1.93	<0.815	3940	<16.1	56.8	1000	51.8	272.0
2-1	393.0	<2.46	296.0	<6.58	791.0	1750	<83.0	<83.0	4030	<16.4	198.0	12.2	20.3	856.0
3-1	4850	13.5	<163.0	<13.1	609.0	2930	199.0	<81.5	5030	<32.6	97.0	141.0	13.1	2290
3-2	2330	<2.44	157.0	<6.50	623.0	2340	144.0	<81.5	4260	<16.3	94.0	143.0	12.9	1680
3-3	4600	<8.44	<164.0	<13.1	655.0	4050	305.0	<80.5	5150	<32.8	105.0	119.0	12.6	3030
4-1	1070	<2.46	382.0	<6.57	955.0	23.6	<8.15	<8.15	3960	<16.4	45.9	1340	68.2	138.0
4-2	1340	<2.45	483.0	<6.54	1490	31.3	<8.15	<8.15	4340	<23.7	65.4	1870	102.0	206.0
4-3	863.0	<2.45	319.0	<6.52	963.0	7.91	<8.20	<8.20	4220	<16.3	38.6	1210	61.1	91.3
5-1	728.0	<2.47	<82.4	<6.59	340.0	4370	172.0	<8.20	2090	<16.4	31.8	27.5	5.36	3430
6-1	2080	<2.46	365.0	12.0	738.0	1400	52.7	<8.15	3560	<16.4	57.4	1010	71.0	2690
6-2	2030	<2.47	341.0	11.3	696.0	1160	44.9	<8.25	5230	<16.4	53.9	1000	83.0	2350
6-3	2060	<2.44	310.0	12.8	627.0	1190	35.6	<8.30	4610	<16.3	50.5	912.0	68.8	1960
8-1	651.0	4.19	396.0	9.05	817.0	22.2	<0.815	<0.815	4260	25.5	53.5	1320	85.8	79.3
8-2	621.0	2.45	346.0	10.5	816.0	8.56	<0.815	<0.815	3800	59.5	47.1	1740	125.0	67.4
8-3	719.0	4.42	353.0	14.6	761.0	7.44	<0.830	<0.830	4030	52.2	49.8	1530	97.0	63.3
9-1	616.0	5.73	343.0	9.1	812.0	34.3	1.57	<0.830	3420	67.8	46.6	2130	119.0	99.2
9-2	731.0	3.57	384.0	13.2	756.0	30.2	0.979	<0.810	3500	52.0	47.2	1940	104.0	85.6
9-3	524.0	<2.98	312.0	7.16	781.0	23.8	<0.815	<0.815	3210	32.1	41.6	1480	107.0	79.4

* Concentrations of Sb and Se are included for information only since the analytical method has not yet been fully tested.

APPENDIX III TABLE 2 CLINTON CREEK SEDIMENT CHEMISTRY DATA, JULY 3, 1982
(all concentrations given in mg/kg dryweight unless otherwise noted)

STATION	CN w/w*	Ag	Al	As	Ba	Be	Ca	Cd	Cr	Cu	Fe	Hg	K	Mg
1-1	<3	<4.93	12700	4.27	785.0	0.304	5950	<0.58	28.9	14.5	15500	0.172	854	3720
1-2		<4.91	15200	5.11	701.0	0.475	7130	<0.57	33.5	13.5	17800	0.170	1230	4470
1-3		<4.88	19800	10.4	1130	0.455	7180	<0.58	63.7	25.8	28000	0.170	2090	7060
2-1	<3	<4.80	12700	15.5	1040	0.167	7620	<0.57	870.0	20.7	69200	0.253	1175	90500
2-2		<4.93	14100	13.6	773.0	0.214	7660	<0.58	792.0	18.9	57600	0.243	1240	80200
2-3		<4.90	16000	17.2	883.0	0.238	7030	<0.57	645.0	21.7	56100	0.375	1540	56400
3-1	<3	<4.85	14300	37.0	368.0	0.533	23400	3.21	192.0	105.0	62900	1.21	1740	26700
3-2		<4.98	15700	34.6	402.0	0.547	27100	3.09	231.0	96.4	59700	1.21	1920	32600
3-3		<4.98	14300	31.8	310.0	0.531	22900	2.42	302.0	87.4	55300	1.09	1890	37800
4-1	<3	<4.84	16200	13.1	228.0	0.677	18400	<0.57	56.3	20.1	31800	0.167	1250	6960
4-2		<4.97	17200	16.7	262.0	0.646	11800	<0.58	64.8	21.8	34600	0.167	1370	7450
4-3		<4.97	16100	9.82	199.0	0.505	9990	<0.58	39.0	18.4	27600	0.167	1150	6740
5-1	<3	<4.97	13400	19.1	1320	0.224	18300	0.84	566.0	36.2	67000	0.342	1490	34200
5-2		<4.84	12900	19.8	1350	0.234	17600	0.82	582.0	36.9	75700	0.368	1320	32000
5-3		<4.79	12800	18.2	1180	0.223	15600	0.93	560.0	35.4	71600	0.375	1270	31000
6-1	<3	<4.79	14700	14.4	315.0	0.311	10700	<0.56	198.0	26.7	31700	0.305	1110	21800
6-2		<4.94	15300	19.2	286.0	0.314	11600	<0.58	210.0	22.8	33100	0.243	1150	22000
6-3		<4.96	15900	12.9	371.0	0.381	13000	<0.58	250.0	25.2	35400	0.390	1300	23200
7-1	<3	<4.93	5000	2.80	188.0	<0.492	3450	<0.58	1620	5.96	67000	1.07	42.0	275000

* w/w Means mg/kg wet weight, total sample. All other measurements in this table are given in mg/kg dry weight for the potion passing a 150 um sieve.

APPENDIX III TABLE 2 CLINTON CREEK MINE - SEDIMENT CHEMISTRY DATA, July 3, 1981 (continued)
(all concentrations given in mg/kg dryweight unless otherwise noted)

STATION	Mn	Mo	Na	Ni	P	Pb	Sb*	Se*	Si	Sn	Sr	Ti	V	Zn
1-1	220.0	<2.46	268.0	17.6	524.0	<6.57	<0.815	<0.815	3530	21.4	46.9	1250	46.0	45.4
1-2	305.0	<2.46	378.0	15.0	579.0	<5.73	<0.815	<0.815	2430	31.2	56.3	1620	54.6	49.9
1-3	1030	<2.44	340.0	43.9	768.0	8.28	<0.795	<0.795	3370	29.2	62.0	1160	61.8	98.4
2-1	1150	<2.40	214.0	1310	414.0	<6.41	2.71	<0.815	3680	16.9	64.9	518.0	40.0	81.3
2-2	1030	<2.46	265.0	1080	439.0	<6.57	2.74	<0.820	3570	<16.4	66.3	657.0	43.6	75.0
2-3	1070	<2.46	269.0	879.0	509.0	<6.54	2.35	<0.810	4420	<16.4	63.0	759.0	48.0	84.2
3-1	2230	12.9	160.0	324.0	1300	39.3	6.57	11.0	5040	<16.2	153.0	103.0	44.6	429.0
3-2	2400	9.72	206.0	409.0	1400	34.0	5.67	10.1	5490	<16.6	162.0	153.0	46.8	385.0
3-3	2440	9.04	199.0	389.0	1190	32.8	6.32	9.97	4600	<16.6	138.0	84.6	42.2	338.0
4-1	590.0	<2.42	584.0	25.6	949.0	<6.44	<0.815	<0.815	2720	50.8	110.0	2270	79.7	56.9
4-2	610.0	<2.48	551.0	32.1	920.0	<6.62	<0.835	<0.830	3030	56.3	76.9	2250	84.9	61.3
4-3	477.0	<2.48	645.0	17.4	1030	<6.62	<0.83	<0.830	3990	35.6	63.8	1870	69.7	55.2
5-1	1180	<2.48	333.0	875.0	913.0	<6.63	3.66	2.49	4110	<16.6	138.0	633.0	45.5	114.0
5-2	1340	<2.42	270.0	884.0	933.0	<6.45	3.83	2.72	4540	<16.1	116.0	606.0	45.0	115.0
5-3	1220	<2.40	210.0	822.0	863.0	<6.38	3.57	2.50	3700	<16.0	109.0	630.0	44.2	110.0
6-1	565.0	<2.39	399.0	240.0	882.0	<6.38	1.52	<1.09	3650	22.3	75.2	1140	55.0	71.2
6-2	725.0	<2.47	427.0	274.0	778.0	<6.59	1.30	<0.864	4230	28.9	75.5	1210	57.2	74.8
6-3	741.0	<2.48	501.0	301.0	860.0	<6.61	1.39	<0.895	2980	37.2	86.3	1420	58.0	77.5
7-1	619.0	<7.39	<247.0	2260	<73.9	<19.7	1.63	<0.815	5450	<49.3	27.7	115.0	20.7	13.3

* Concentration of Sb and Se are included for information only since the analytical method has not yet been fully tested.

APPENDIX III TABLE 3 LAFORMA SEDIMENT CHEMISTRY DATA, JUNE 11, 1981
(all concentrations given in mg/kg dryweight unless otherwise noted)

STATION	WET/DRY RATIO	CN w/w*	Ag	Al	As	Ba	Be	Ca	Cd	Cr	Cu	Fe	Hg	K	Mg
1-1	1.13	<0.6	<4.97	22200	204	329	0.968	5890	0.844	23.4	62.8	27700	0.170	2570	5390
1-2			<4.98	22600	200	337	0.995	5990	0.739	23.2	63.2	28200	0.165	2430	5470
1-3			<4.90	23000	199	331	0.938	5890	0.890	34.1	58.4	28200	<0.189	2530	5440
2-1	1.27	<4.0	<4.98	24400	326	389	1.01	6740	0.797	25.6	94.0	27500	0.256	3060	6030
3-1	1.18	<0.4	<4.94	15100	436	465	0.815	6710	1.35	14.0	90.4	21100	<0.192	2140	3770
3-2			<4.86	17000	423	449	0.917	7090	1.25	15.5	102	22400	<0.179	2290	4230
3-3			<4.94	14200	432	559	0.749	6710	1.04	14.3	96.0	21100	0.260	2070	3570
4-1	1.07	<0.4	<4.96	15500	48.0	454	0.330	9050	<0.580	54.1	16.2	37400	0.170	1660	5940
4-2			<4.87	15900	43.4	519	0.389	9460	<0.570	62.4	16.9	40700	0.170	1630	6250
4-3			<4.88	14000	40.5	472	0.341	8230	<0.570	61.7	17.0	46000	0.253	1640	5760
5-1	1.11	<0.6	<4.90	19800	344	498	0.783	8260	0.856	31.5	93.2	25500	0.382	2110	6070
5-2			<4.81	18200	337	481	0.769	7650	1.04	30.4	99.3	25800	0.430	1880	5930
5-3			<4.95	17000	327	532	0.741	7360	0.987	34.7	86.0	27100	0.371	1800	5610

* w/w Means mg/kg wet weight, total sample. All other measurments in this table are given in mg/kg dry weight for the portion passing a 150 um sieve.

APPENDIX III TABLE 3 LAFORMA SEDIMENT CHEMISTRY DATA - JUNE 11, 1981 (continued)
(all concentrations given in mg/kg dryweight unless otherwise noted)

STATION	Mn	Mo	Na	Ni	P	Pb	Sb*	Se*	Si	Sn	Sr	Ti	V	Zn
1-1	1880	24.7	295	8.12	676	54.6	1.31	<0.835	4470	<16.6	59.1	769	51.7	154
1-2	1930	24.1	316	8.06	699	54.2	1.28	<0.830	4410	<16.6	59.2	769	52.8	150
1-3	1830	21.1	283	16.8	633	49.0	1.42	<0.820	3980	<16.3	52.8	859	55.5	136
2-1	1160	14.6	334	10.8	590	59.1	1.54	<0.830	4560	<16.6	68.9	591	50.4	171
3-1	1090	12.3	258	<6.59	654	93.5	3.43	<0.835	4410	<16.5	67.5	488	31.5	194
3-2	1220	15.4	289	7.48	656	79.9	2.19	<0.825	4750	<16.1	73.8	492	33.8	184
3-3	1000	11.1	241	<7.73	722	86.4	2.19	<0.825	3920	<16.4	67.0	496	32.0	169
4-1	1580	<2.48	422	25.2	1500	<6.61	<0.820	<0.820	4200	17.4	107	967	107	74.5
4-2	1870	<2.44	432	32.2	1550	<6.50	<0.815	<0.815	4940	19.5	116	995	120	79.0
4-3	1470	<2.44	389	36.4	1620	<6.50	<0.815	<0.815	4490	35.8	90.7	1120	140	81.0
5-1	1080	9.13	378	17.6	780	64.0	1.96	<0.830	4690	<16.4	129	575	48.9	149
5-2	1100	8.48	363	18.4	751	68.5	2.03	<0.795	3880	<16.0	123	528	47.1	156
5-3	973	9.22	353	19.9	810	62.5	1.71	<0.820	4220	<16.5	114	589	56.8	141

* The concentration of Sb and Se are included for information only since the analytical method has not yet been fully tested.

APPENDIX III TABLE 4 LONE STAR - SEDIMENT CHEMISTRY DATA, June 22, 1981
(all concentrations given in mg/kg dryweight unless otherwise noted)

STATION	CN w/w*	Ag	Al	As	Ba	Be	Ca	Cd	Cr	Cu	Fe	Hg	K	Mg
2-1	<3	31.6	898.0	65.8	206.0	<0.331	270.0	3.07	3.5	84.3	193000	17.7	480	109.0

STATION	Mn	Mo	Na	Ni	P	Pb	Sb*	Se*	Si	Sn	Sr	Tl	V	Zn
2-1	11.5	<4.96	<166.0	117.0	<49.6	957.0	0.969	<0.825	1700	<33.1	11.5	119.0	<6.62	216.0

* Concentrations of Sb and Se are included for information only since the analytical method ohas not yet been fully tested.