AN ENVIRONMENTAL REVIEW OF THE CLINTON CREEK ABANDONED ASBESTOS MINE, YUKON, CANADA

Prepared for:
Indian and Northern Affairs Canada
Waste Management Program, Whitehorse, Yukon

By:
Royal Roads University - Applied Research Division

March 1999

ROYAL ROADS UNIVERSITY

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EXECUTIVE SUMMARY

The Clinton Creek Asbestos Mine is located approximately 100 km northwest of Dawson City in the Yukon Territory. Cassiar Asbestos Corporation Ltd. operated the mine from 1967 to 1978. In 1974 waste rock deposited on the north-facing slope of the Clinton Creek valley failed and blocked the valley. This created a landslide dam and impoundment referred to as Hudgeon Lake. Down-slope movement of the tailings deposits also resulted in the blockage of Wolverine Creek, a smaller tributary to Clinton Creek. From 1978 to 1991 Cassiar Asbestos Corporation Ltd. and their successors, Princeton Mining Corporation, undertook various mitigation efforts to address the legacy of environmental impacts and risks associated with the abandoned Clinton Creek mine site. Despite these efforts, ongoing environmental impacts and risks persist at the mine site. In recognition of these risks and impacts, the Applied Research Division (ARD) Royal Roads University on behalf of Indian and Northern Affairs Canada (DIAND), Waste Management Program, Yukon, carried out an environmental review of the Clinton Creek mine site. The objectives of this review were to document current conditions, compare them with historical site data and prepare a preliminary environmental risk assessment. Activities undertaken to fulfill these objectives included a desktop review of existing site information and field investigations. This document presents the results and recommendations of the environmental evaluation and preliminary risk assessment.

The field investigation field program was conducted in September 1998 by a team comprising participants from DIAND Waste Management, Royal Roads and W.R. Ricks Consulting.

An inventory and assessment of aquatic habitat and resources, consisting of minnow trapping, gillnetting, electrofishing, invertebrate drift samples, and plankton samples, was carried out in the Clinton Creek watershed. Results were compared to a similar assessment carried out in 1980. Overall, the most significant changes in fish habitat since 1980 appear to have occurred in the upper reaches of Clinton Creek, making fry habitat and accessibility increasingly poor in this area. By contrast, noticeable improvements in habitat have occurred downstream. Habitat conditions in lower zones of Clinton Creek remain relatively stable and are similar in characteristic to a reference location situated in Mickey Creek. The assessment suggests a possible increase in the Chinook fry population of Clinton Creek and a significant shift in the composition of fry populations from freshwater Arctic Grayling to anadromous Chinook salmon since 1980. No significant improvements were observed in the Arctic grayling population of Hudgeon Lake since 1980. The results place some question as to the current existence of any viable resident grayling population in the Clinton Creek watershed. More recent studies from Hudgeon Lake in 1999, however, suggest that a small summer resident (temporary) population of fish may be migrate there.

A quantitative assessment of the terrestrial habitats was conducted using ground cover vegetation surveys in representative areas directly and indirectly affected by the mine tailings or waste rock. Ground vegetation in the area of the tailings pile site was extremely scarce and plant diversity within the plots very low. Indirect effects of smothering from tailings are also evident. Ground vegetation species at the waste rock

site was not unlike that of the tailings pile site. The re-establishment of trees and vegetation in general, nevertheless, has been much greater at the waste rock site than at the tailings piles. Observations of mats of chrysotile asbestos in the lower branches of trees at a height corresponding to that of the winter snow pack suggests some potential for the mobilization of asbestos in the terrestrial environment.

A geochemical assessment of the waste rock and tailing materials was undertaken to determine the potential impact of these materials on the surrounding aquatic habitat. This consisted of soil, sediment and water sampling and analysis. A total of 32 soil samples were collected from the site. In addition 27 water and 23 sediment samples were taken from Hudgeon Lake, Wolverine Creek, Fortymile River and three reference locations. The soil, sediment and water samples were analyzed for metals, metalloids and asbestos. Inorganic non-metallic parameters were also determined in the water samples. The soil and water samples consistently demonstrated elevated pH indicating alkaline conditions. Antimony, lead, molybdenum, silver and tin were generally below the detection limits in soil/sediment samples. Detection limits for these elements, however, were high due to matrix interference caused by elevated chromium and nickel concentrations found in the samples. Concentrations of arsenic, barium, chromium and nickel exceeded the CCME guidelines for residential parkland land use in substrate samples. These elements were not detected in the water samples. The high pH of soil samples likely keeps the metals out of solution and prevents their movement into surrounding waters. Asbestos concentrations in water were elevated but comparable to previous results. An anoxic condition was noted in a sample collected from the lower depths of Hudgeon Lake.

For a number of water samples the concentrations of aluminum, iron, manganese and selenium exceed the CCME guidelines for freshwater aquatic life or drinking water. Manganese can be eliminated as a metal of concern unless humans use the surface waters for drinking water supplies. Given the natural geological conditions in the area, it is unlikely that aluminum, iron and selenium in freshwater have resulted in elevated risks to aquatic biota or terrestrial receptors in the vicinity of the rivers and creeks. Resident biota are expected to be adapted to the range of environmental exposure concentrations for these three naturally-occurring metals/metalloids. These are not likely to be contaminants of concern based on chronic mobilization or in association with massive downstream materials transport.

The difficulties with stabilization of the waste rock and tailings deposits have caused, and will continue to lead to, their chronic slumping and redistribution. The identified ecological receptors at risk from chronic mobilization of materials from unstable waste rock and tailings deposits include terrestrial mammals, including humans and asbestos inhalation risks; aquatic mammals (i.e., beaver colonies) anadromous fish populations (Chinook salmon); and non-anadromous fish populations and communities. Chronic risks from the abandoned mine owing to geochemical mobilization and release of metals/metalloids or other substances to the water appear to be unlikely. Anoxic bottom waters in Hudgeon Lake, however, may represent a worst-case for reduced geochemical stability and metal release, and as a source of risk to ecological receptors in and downstream of the lake. The probability and projected consequences of various forms of moderate to massive failures of the unstable waste material slopes and impoundments have not been assessed in this study. The impact from a catastrophic failure is expected to include direct fish and fisheries habitat loss through smothering and flooding, and possible risks to human life and property from a massive flooding event.

Ecosystem components that are deemed to merit further assessment of risks include anadromous and non-anadromous fish populations and habitat, and fish forage species such as aquatic invertebrates. Terrestrial ecological receptors, other than humans, can provisionally be excluded from a more detailed ecological risk assessment. If, however, unique habitats and/or threatened or endangered species are identified in the Clinton Creek watershed below the abandoned mine site, then additional consideration will need to be given to these terrestrial ecological receptors.

Human health related risks which merit further examination include cancer risks due to the inhalation of friable chrysotile asbestos fibres in the terrestrial environment based on occasional site visits; cancer and other health risks from the ingestion of water with elevated levels of chrysotile asbestos fibre levels; and the risk of loss of life, other traumatic injury or of property damage due to severe flooding.

With regard to the continued management and characterization of the ecological and human health risks associated with the abandoned Clinton Creek mine sites, the following tasks are recommended:

- Completion of additional geophysical studies on the short and long term stability of the waste rock materials and the tailings piles.
- Additional aquatic sampling (i.e., fish, invertebrates) in the Clinton Creek watershed to establish broader, seasonally-variable population estimates; and additional water quality assessment in different areas of Hudgeon Lake – particularly anoxic conditions detected at lower depths.
- Assessment of aluminum and selenium tissue concentrations in stream invertebrate and/or fish tissue samples to ascertain that these compounds are not bioaccumulated at levels that would lead to adverse effects on aquatic biota.
- Execution of studies using flume-type mesocosms to examine the chronic effects of water-borne chrysotile asbestos and suspended solids from the waste rock and tailings deposits across a range of concentrations on juvenile and adult salmonids, particularly Chinook salmon.
- Limited measurements of asbestos fibre concentrations in air around the abandoned open pit mine and tailings deposits.
- In lieu of any viable structural engineering solutions for stabilizing the waste rock and tailings areas from chronic or catastrophic failure, the use or promotion of native vegetation including ground cover (such as local/native colonizing grasses), and trees to secure the slopes in the tailings and waste rock areas and promote natural regeneration of the mine site.

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1. INTRODUCTION

1.1 Background

The Clinton Creek Asbestos Mine (64^{O} 22' 23" N, 140^{O} 42' 50" W) is located approximately 100 km northwest of Dawson City in the Yukon Territory. It is adjacent to Clinton Creek approximately 9 km upstream of its confluence with the Fortymile River (Map 1.1). Porcupine and Wolverine creeks are local tributaries of Clinton Creek.

Cassiar Asbestos Corporation Ltd. operated the mine from October 1967 until August 1978 when it was closed due depletion of its economic reserves. The mill buildings and associated town site, located 10 km southeast of the mine, were auctioned off in 1978. Cassiar Asbestos Corporation Ltd., later Princeton Mining Corporation still owns the mine site.

During operation, ore was extracted from the bedrock in three open pits along the south side of Clinton Creek. The waste rock was deposited over slopes adjacent to the open pits. The ore was transported by an aerial cable tramway to the mill site that was located on a flat ridge, across Clinton Creek and north of the mine site. A dry hammer mill process was used to extract asbestos fibre from the ore. The tailings were then deposited in two lobes over the slopes of the mill site.

Waste rock deposited on the north-facing slope of the Clinton Creek valley failed and blocked the valley in 1974. This created a landslide dam now referred to as Hudgeon Lake. Waste rock placed along the Porcupine Creek valley also formed an impoundment across the creek. The down-slope movement of the tailings deposits along the two lobes resulted in the partial blockage of Wolverine Creek, a smaller tributary to Clinton Creek.

The waste rock and tailings continue to move and the long-term stability of the three blockages is not known. The probability of a breach failure in any of the blockages is considered high (Stepanek and McAlpine, 1992). Clinton Creek flows into Fortymile River and then into the Yukon River. A breach of an existing blockage may increase the potential for the chronic or massive downstream movement of asbestos-containing sediments discharged into the creek. The Yukon River is a trans-boundary river: It enters Alaska approximately 50 km downstream from the abandoned mine site.

1.2 Project Objectives

The overall purpose of this project is to evaluate the existing and future off-site risks associated with unstable waste rock and tailing deposits around the abandoned mine site on Clinton Creek.

Specific objectives of this study are to -

- Re-evaluate the expected fate and transport of waste rock, tailings piles, and associated impounded water through a review of existing information as well as a re-analysis of new survey data;

- Identify terrestrial and aquatic receptors and resources at risk (including humans) from the discharge of waste materials into Clinton Creek and the larger watershed;

- Determine retrospectively the ecological risks to fish and other aquatic biota associated with past releases of suspended sediments, asbestos fibres, and/or metals/metalloids;

- Refine predictions of future human health and ecological risks associated with either chronic waste materials mobilization into the watershed or various levels of catastrophic failure and downstream transport; and

- Communicate risks and identify risk management options for the Clinton Creek mine site.

To achieve the objectives outlined above, a historical and desktop review of existing information, including departmental correspondence, on the Clinton Creek abandoned asbestos mine was conducted in August 1998. A field program followed this in September 1998. Investigations and activities conducted by a team comprising participants from DIAND Waste Management, Royal Roads University, and W.R. Ricks Consulting, Whitehorse, included:

- Measurement of bathymetry of Hudgeon Lake and calculation of the volume of water in the lake;

- Collection of samples for the geochemical characterization of tailings and waste rock deposits, especially with regard to asbestos, metal and metalloid concentrations;

- Establishment of current conditions of terrestrial and freshwater (primarily fish) habitat in areas affected by mine tailings and waste rock in Clinton Creek;

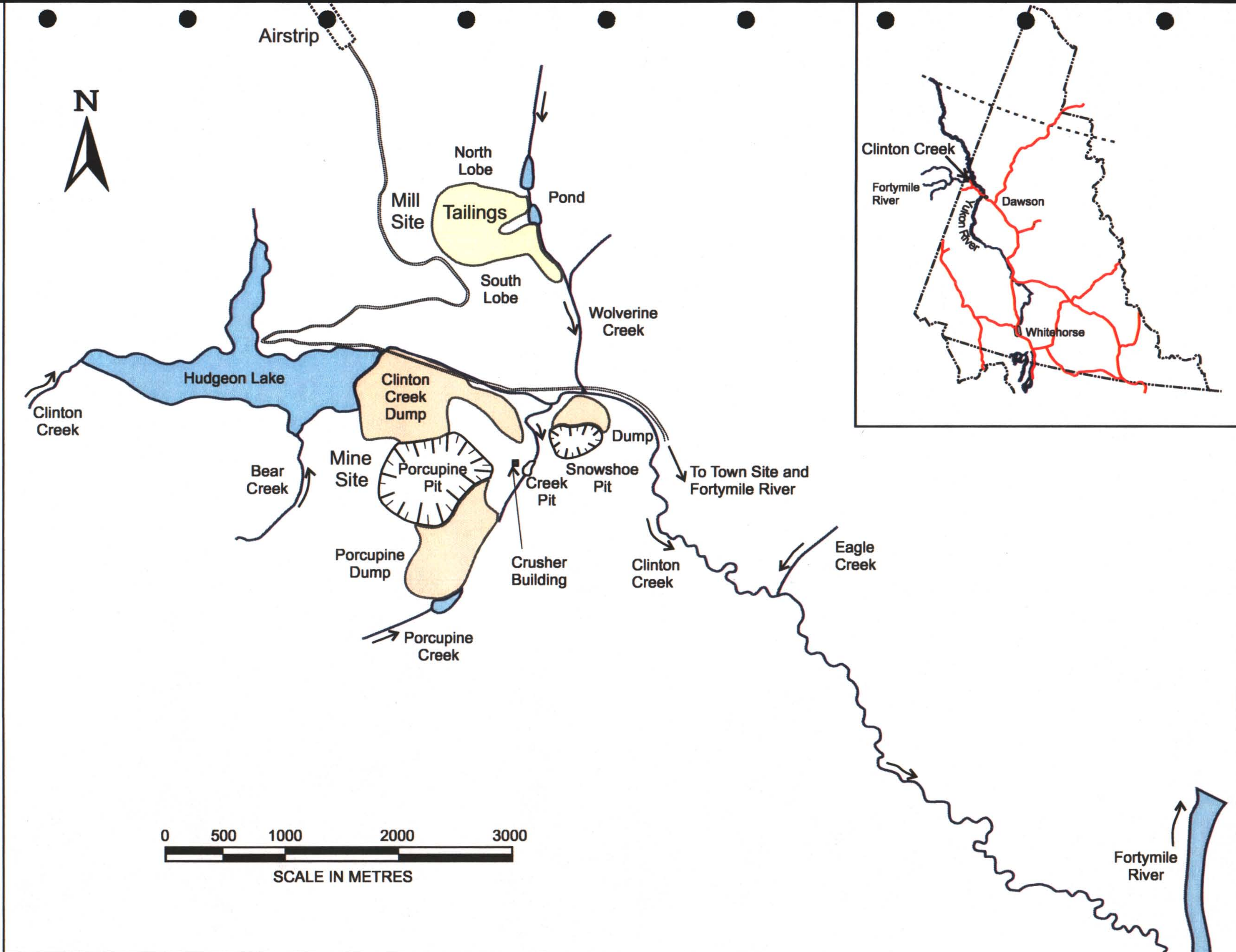
- Sampling of water, sediment and fish along Clinton Creek, downstream of the mine to assess waste materials redistribution using chemical tracers and asbestos (in riverine sediment deposits);

- Quantitative assessment of the terrestrial habitats using vegetation surveys in areas directly and indirectly affected by the mine tailings and/or waste rock;

- Collection of representative plant samples and archiving for future contaminant analysis pending the analytical results from the accompanying soil samples;

- An assessment of site use by potential mammalian and avian wildlife.

The field investigation was followed by laboratory analysis for metals and asbestos. This report presents the results and recommendations of the environmental evaluation and preliminary risk assessment.



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Indian and Northern Affairs Canada
Waste Management Program
Yukon Region

CLINTON CREEK ABANDONED ASBESTOS MINE

GENERAL SITE PLAN

Project No: 98-008 | Date: March 1999 | **Figure 1.1**

2. REVIEW OF EXISTING INFORMATION

2.1 Regulatory History

The regulatory history of the Clinton Creek mine presented in the following section is based on documentation provided by DIAND. The mine ceased operations in 1978. The earliest documentation provided on the post operational regulatory history of the mine site is dated 1986. The most recent piece of correspondence is dated March 23, 1993. Accordingly it should be noted that the following history has been interpreted from incomplete documentation.

Clinton Creek asbestos mine was operated from October 1967 to August 1978 by the Cassiar Asbestos Corporation Ltd. Cassiar owned the land where the excavation pits, mill site and town are located. The Mine was closed when its economic ore reserves were depleted, and when operational costs exceeded expected revenues. Cassiar auctioned off the mill buildings and town site in 1978.

From 1978 to 1987, the Cassiar Asbestos Corporation undertook a series of decommissioning activities. These included –

- removal of structures from the town site, removal of the main segments of the concentrator,
- removal of most mining equipment and facilities except the primary crusher,
- re-vegetation through hydro-seeding of the town site, waste dumps and tailings piles, and
- installation of erosion control measures.

Erosion control measures were designed to improve the flow regime and stabilize Clinton and Wolverine Creeks. These activities resulted in mixed success: Some structures failed and some were effective (Indian and Northern Affairs Canada, no date).

Under the auspices of the 1972 Northern Inland Waters Act, the Yukon Territory Water Board issued a water license to Cassiar Asbestos Corporation Ltd. in 1974. The water license granted the Cassiar Asbestos Corporation Ltd. approval to remove water from and deposit sewage to the Fortymile River for the purposes of serving the town site. In 1978 a new water license was approved for the mill site. The mill site license expired in 1982, but in 1983 the license was extended to 1987. The rationale for extending the water license was that it would provide a regulatory basis for achieving satisfactory mine abandonment. In accordance with the terms of the water license, which expired in September 1987, Cassiar Mining Corporation submitted a rehabilitation and abandonment plan to the Yukon Territory Water Board.

Cassiar Mining Corporation commissioned Klohn Leonoff Consulting Engineers to prepare the abandonment plan for the mine. The plan, titled "Abandonment Plan for Clinton Creek Mine," was submitted to the Yukon Territory Water Board in September 1986. Although the Abandonment Plan recognized ongoing mass movements of the waste and tailings piles and the resulting down-cutting, channel armoring and deposition in the creeks, the plan concludes that the "Clinton Creek waste dump and tailings piles are considered to be in suitable condition for final abandonment" (Geo-Engineering, 1986).

In October 1986, DIAND retained Geo-Engineering Ltd. to complete a detailed review of the Klohn Leonoff Abandonment Plan (Geo-Engineering, 1986). Geo-Engineering provided a critical review of the Abandonment Plan made recommendations to the Yukon Territory Water Board. The Geo-Engineering report states that the "submitted 'Abandonment Plan' is deficient in the evaluation of possible impacts …as well as in outlining of [sic] appropriate future actions, by the company as well as by the government". Geo-Engineering recommended that the Yukon Territory Water Board find the Abandonment Plan deficient, request Cassiar address the deficiencies and request Cassiar to define their position if the impacts exceed those predicted in the plan. The report also advised the Board to seek advice regarding public consultation.

The Yukon Territory Water Board held public hearings on the abandonment plan in Whitehorse in January 1987. The Board subsequently recommended acceptance of the plan and extension of the water license. The Water Board also recommended that the $400,000 security bond posted by Cassiar at the time of the original license application be retained to establish a monitoring and remote warning system to mitigate the potential risk of high water levels from stream blockage.

The Yukon Territory Water Board and DIAND could not agree on a satisfactory abandonment plan. The Minister of Indian and Northern Affairs refused to sign the proposed water license amendment which prescribed conditions of abandonment. The Minister wished to avoid potentially exposing the Crown to long term liability for the site. The water license was allowed to expire and DIAND retained the bond (Indian and Northern Affairs Canada, no date).

In 1987, counsel from DIAND Legal Services responded to legal questions from DIAND Water Resources Division regarding the mine site (Indian and Northern Affairs Canada, 1987). Counsel advised that the possible case against Cassiar for violations of the Northern Inland Waters Act was weak. However, Cassiar may be liable in a civil action under a nuisance tort. Finally, the risk of Crown liability was considered low.

In early 1988 DIAND, in consultation with the Yukon Department of Renewable Resources, developed a Minesite Management Plan (Indian and Northern Affairs Canada, 1988). The Minesite Management Plan was designed to serve as a basis for an agreement on the ongoing monitoring and risk management activities to be undertaken by Cassiar and DIAND. Risk management activities set out in the Management Plan included signage, periodic media broadcasts, annual site monitoring and decommissioning of stream crossings. The Plan also stated that Cassiar would be responsible for any increased risks that required remedial actions. DIAND held negotiations with Cassiar and reached a verbal agreement that Cassiar would address the requirements outlined in the Minesite Management Plan in return for the bond.

In 1988 Cassiar removed the primary and secondary crushing units from the crusher building complex at the mill site. In 1989 Cassiar erected a series of warning signs and undertook additional clean up of the abandoned mine site. However, DIAND noted in August 1989 that the culverts at the outlet of Hudgeon Lake remained in place and were encumbered with debris.

In August 1988, Environment Canada conducted a site visit at the mine for the purposes of inspecting potential PCB contamination (Environment Canada, 1988). The presence of PCBs was confirmed and Environment Canada issued an order to Cassiar for the clean up and secure storage of PCB wastes in November 1988. The PCB wastes were cleaned up to the satisfaction of Environment Canada by August 1989.

In late 1989 Cassiar requested that the bond held in association with the expired water license be returned. DIAND responded that there were outstanding issues and that the matter was being referred to legal review.

DIAND made a request in 1990 to the Canadian Department of Justice to determine if Cassiar's operations at Clinton Creek may have violated the Yukon Quartz Mining Act, the Yukon Placer Mining Act, the Territorial Lands Act, the Canadian Environmental Protection Act or the Fisheries Act (Department of Justice Canada, 1990). Counsel for the Department of Justice responded that there may have been a breach of the Fisheries Act and the Canadian Environmental Protection Act, however, further instruction and consultation would be required to determine the likelihood of a successful prosecution.

By 1991 DIAND had received eleven requests for release of the bond. DIAND prepared a comprehensive analysis of the situation and a recommended action plan. The DIAND review advocated reopening negotiations with Cassiar (now Princeton) to have the corporation complete the tasks set in 1988 in return for the bond. The Yukon Water Board supported this approach. DIAND and Princeton met in September 1991 and the meeting was followed up with a letter from DIAND outlining the work required in return for relinquishment of the bond. Princeton provided no written agreement.

Following the September meeting Princeton undertook further remedial activities at the Clinton Creek site (Indian and Northern Affairs Canada, 1992). These activities included the re-establishment of signage, partial filling of the crusher building, placement of fill in the sewage plant, remediation of Hudgeon Lake outlet and other minor measures to mitigate on site hazards. Princeton sent a report to DIAND documenting these activities in November 1991 and requested that DIAND return the bond.

In February 1992, DIAND staff prepared a briefing note recommending that the bond be returned to Princeton. However, snow cover at the site prevented DIAND from properly evaluating the remedial work completed by Princeton.

2.2 Mines Site and Waste Rock Dumps

The Clinton Creek Abandoned Asbestos Mine is within the unglaciated Yukon – Tanana Upland with terrain consisting of a series of ridges (Photograph 2-1). The valley bottoms of the ridges are at an elevation of 400 m with the highest levels reaching 610 m above sea level. The site has been described to be in a region of widespread discontinuous permafrost (Stepanek and McAlpine, 1992).

Asbestos was mined from a complex assemblage of rocks that includes ultramafic, igneous and metamorphous rocks, such as serpentinite, diorite, amphibolite, schist, shale siltstone and limestone (Stepanek and McAlpine, 1992). The ore body itself comprised chrysotile asbestos veinlets embedded in jade green serpentine.

The production rate, when it started in 1968 was approximately 2500 tons per day and increased to 5118 tons per day in 1975. In 1975 approximately 1.5 million tons of ore were milled with a recovery of 5.85% and by the end of the year, an estimated 75 million tons of waste had been removed from the mine (Fisheries and Environment Canada, 1977).

The mine site consists of three open pits – the Porcupine, Snowshoe and Creek pits (Figure 1-1). The Porcupine and Snowshoe pits are located on a hilltop on the south side of Clinton Creek. The Creek pit is located on the original alignment of Porcupine Creek (Photograph 2-2). The Porcupine pit is the largest of the three (Photographs 2-3 and 2-4).

Waste rock from the three open pits was deposited on the valley slopes adjacent to the pits. This practice created three waste rocks dumps (Clinton, Porcupine, and Snowshoe). The last of the waste rock materials was consigned to the dump sites in the summer of 1977. The waste rock predominantly consists of argillite. The volume of the waste rock piles has been estimated at 60 million tonnes (Roach, 1998). The waste rock consist mainly of argillite, phyllite, platy limestone and micaceous quartzite (Stepanek and McAlpine, 1992). Asbestos fibres are occasionally found amongst the waste rock (Photograph 2-5).

The largest dump, Clinton dump, was created by dumping overburden from the Porcupine pit near the crest of the south slope of Clinton Creek. Shortly after dumping commenced the face of the dump failed and the toe of the waste rock pile spread northward onto the Clinton Creek valley bottom. As the toe of the dump reached the valley floor it began to spread on the permafrost alluvial soil of the valley floor. Subsequent downslope movement of waste rock resulted in the blockage of Clinton Creek and the creation of Hudgeon Lake in 1974 (Photograph 2-6).

In 1978 the surface of Hudgeon Lake measured approximately 408 m, the maximum water depth was approximately 26 m and the surface area was approximately 73 ha (Golder, 1978). The size of the waste rock dam blocking Clinton Creek was estimated to be approximately 0.8 km long and 50 m high (Stepanek and McAlpine, 1992). A discharge channel from Hudgeon Lake developed at the northern perimeter of the dump where the waste rock pile contacts the north slope of Clinton Creek valley. Discharge from the outflow flows across the north side of the waste dump. Mine operators excavated a channel along the eastern extremity of the toe of the waste rock mass to maintain drainage from the lake. The channel is bounded by the valley wall on the north bank and the waste rock piles on the south. The channel has cut into the near surface weathered bedrock on the north bank and the waste rock material on the south bank.

The mining company installed four 1800cm diameter culverts and a rock apron to facilitate outflows from Hudgeon Lake to Clinton Creek. A section of rock weirs and channel armoring was constructed downstream of the lake outfall in 1981. During the 1982 freshet, the creek escaped the armored channel of the creek and undercut the north valley wall. The armored section was reconstructed in 1984. (Stepanek and McAlpine, 1992)

Prior to impoundment the natural grade of Clinton Creek was approximately 0.075% (Golder, 1978). The grade of the creek where it traverses the waste rock pile was measured at approximately 5% in 1978 (Golder, 1978). Clinton Creek is incised with eroded waste rock and bedrock material as a result of increased flow velocity.

Downslope movement of the waste rock piles continues. The movement of the Clinton dump waste rock pile was measured at 60-200 cm/yr in 1978 (Golder 1978). More recent studies measured the rate of movement at 30-50 cm/yr (Roach, 1998).

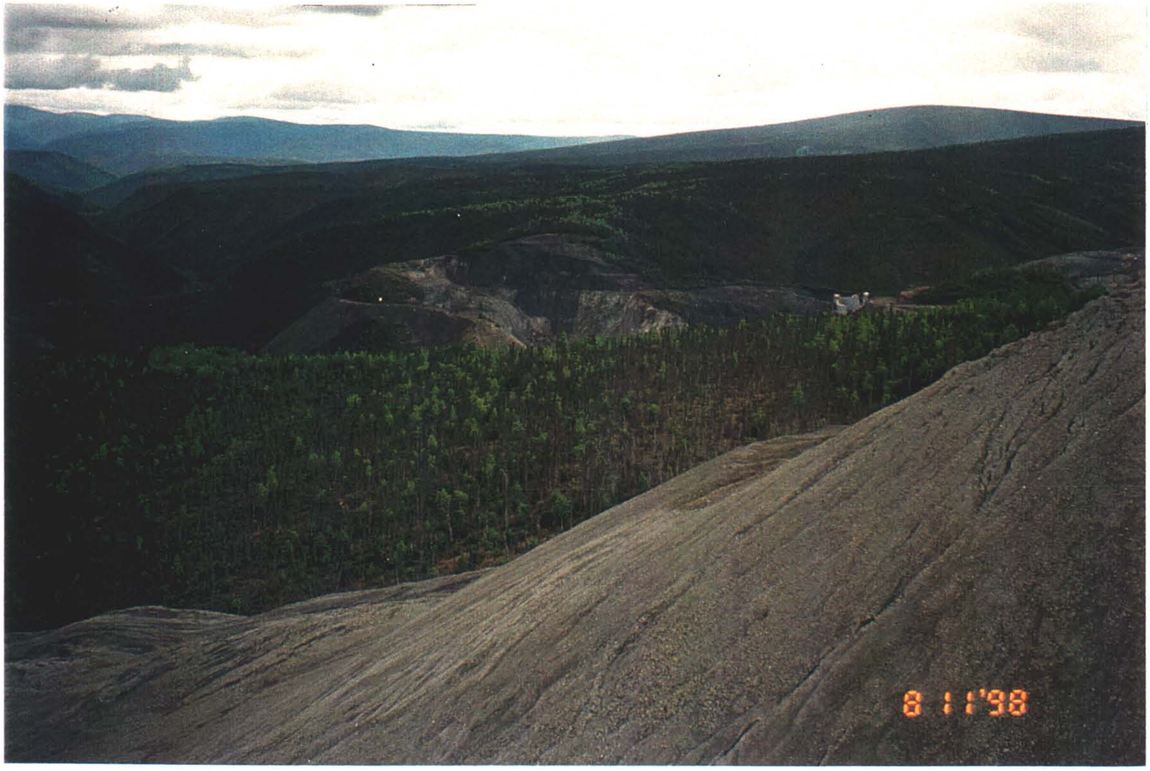
Downslope movement of three million tonnes of waste rock also formed an additional impoundment on Porcupine Creek (Photograph 2-2).

2.3 Mill Site and Tailings Piles

The mill produced approximately one million tonnes of long fiber chrysotile asbestos and almost 12 million tonnes of tailings (Stepanek and McAlpine, 1992). The mill tailings are predominantly composed of serpentine and asbestos fibers. The mill tailings were deposited with a conveyor stacker near the mill on the open west slope of Wolverine Creek valley. The original tailings deposit is known as the south lobe. The south lobe failed in 1974 and a second tailings deposit, the north lobe, was used until the mill was decommissioned in 1976 (Photograph 2-7).

When the south lobe of the mill tailing pile failed it ran down the slope of Wolverine Creek valley and caused the blockage of Wolverine Creek. This blockage resulted in the creation of an unnamed lake. The initial valley blockage was breached almost immediately, and tailings were dispersed approximately 2 km downstream (Stepanek and McAlpine, 1992). Cassiar constructed a rock-lined outfall channel and weirs in 1978 to mitigate impacts and convey Wolverine Creek over the south lobe. At the time of mill closure Wolverine creek was eroding the south lobe tailings pile and resulting in downstream sedimentation of Wolverine and Clinton Creeks (Golder, 1978). The north lobe was moving downslope at a rate of approximately 23 m/yr (Golder, 1978).

Progressive failure of the north lobe began in 1978 and in 1985 the north lobe mass reached Wolverine Creek (Photograph 2-8). Both lobes were terraced in 1978 in expectation that stabilization would be achieved by 1987. Movements in both lobes have been monitored since 1978. Mass movement of the tailings piles continues at rates as high as 19 m/yr (Roach, 1998). Wolverine creek continues to erode both the tailings piles and the east side of Wolverine Creek valley.



Photograph 2-1: View of the mine site from the south lobe of tailings pile. Note tailings in the foreground and characteristic terrain in the background

Photograph 2-2:Creek Crusher overlooking Porcupine Creek Open Pit

Photograph 2-3: Porcupine Open Pit, view of the southern end

Photograph 2-4: Porcupine Open Pit, view of the northern end.

Photograph 2-5: Asbestos fibres amongst waste rocks at the Clinton Waste Rock Dump

Photograph 2-6: Hudgeon Lake looking west from the northeastern shore, near the outlet into Clinton Creek

Photograph 2-7: South and North lobes of tailings in Winter 1999 (Photograph courtesy of P. Roach, DIAND)

Photograph 2-8: Toe of the tailings piles showing the blockage of Wolverine Creek resulting in the formation of two ponds

2.4 Environmental Assessments

A series of environmental assessments have been carried out on Clinton Creek mine. Some assessments were undertaken while the mine was operational, but the bulk of the assessment work has been carried out since the mine was shut down in 1978. These assessments are of two general types: geophysical assessments and biological assessments.

2.4.1 Geophysical Assessments

2.4.1.1 Golder Brawner Associates 1974

Golder Brawner Associates conducted an inspection of waste disposal operations at the mine in 1974 (Golder Brawner Associates, 1974).

Regarding the waste rock piles, their reported stated that -

> "no one can predict the time interval required for the toe regions of the waste [rock] pile to become stable, nor the amount of the total displacements that will occur before the toe regions of the pile come to equilibrium."

They also observed evidence of instability of the mine tailings piles and concluded that -

> "If the water level in Wolverine Creek pond on the upstream side of the tailings rises (or alternatively if invert of the channel is lowered) so that the channel again carries significant surface flows (for example during spring breakup), rapid erosion and down-cutting can be expected to occur.... This will result in additional transport of tailings to downstream areas, and will contribute to suspended solids load in the creek downstream."

Golder Brawner Associates recommended placement of reference points and initiation of a monitoring program. The report also contains a number of mitigation measures for Wolverine Creek and cautions against the continued deposition of tailings to the north lobe of the tailings pile.

2.4.1.2 R.M. Hardy and Associates 1977

In 1977, at the request of the Yukon Territory Water Board, RM Hardy and Associates undertook an analysis of the overall stability at the mine site and made recommendations on requirements for a suitable site rehabilitation and abandonment plan (RM Hardy and Associates, 1977). Their report concluded that it would be impractical to arrest the movement of the waste rock and tailings piles except in localized areas. The study made a series of recommendations on requirements for a stabilization and rehabilitation plan that would accommodate the continued mass movement of the waste rock and tailings piles and maintain proper drainage of the watersheds.

2.4.1.3 Golder Associates 1978

Golder Associates carried out an assessment of the mine site for Cassiar Asbestos Corporation Ltd. in 1978 (Golder Associates, 1978).

Golder measured the horizontal spreading of the waste rock piles at a rate of approximately 1.1 m/yr and determined that the movement was a result of horizontal spreading at the base of the piles. Golder precluded the possibility of horizontal movements based on the internal shearing of dump materials and concluded that the mass movement was a result of "shear displacements within the in situ native foundation soils beneath the base of the dump". Golder suggested that the permafrost in native soils was being insolated by the waste rock and influenced by the infiltration of subsurface water seepage from Hudgeon Lake. Golder concluded that the stability of the waste rock dam had a "generously large factor of safety" and recommended the placement of toe fill to stop the lateral movements of the waste rock piles. Golder also suggested that waste rock movements would likely be naturally slow over time without active mitigation.

Golder's 1978 assessment of the mine site included consideration of the stability of Clinton Creek. Golder recommended installation of a coarse rock erosion-resistant channel lining and energy dissipating weirs to mitigate channel erosion and stream sedimentation. However, the effectiveness of this mitigation was predicated on the prior stabilization of the waste rock piles. As an interim solution, Golder recommended construction of a moderately protected channel to mitigate further lowering of the Clinton Creek channel and guard against further undercutting of native soils and bedrock along the north side of the channel.

Golder also undertook an assessment of the tailings piles and their impact on Wolverine Creek. Golder found that both the south and north lobes continued to move downslope at significant rates. Golder recommended removing materials from the face of the tailings piles to reduce downslope movement of material. Recommendations also included channel upgrades to Wolverine creek, including construction of channel armoring and weir systems, to mitigate sedimentation of Wolverine Creek and downstream watercourses.

The potential risk of airborne fugitive asbestos fibers from the tailings piles was studied. Golder's assessment concluded that the elimination of downslope movement of materials on the tailings pile would preclude the possibility of wind-blown fugitive emissions of asbestos particles. It was determined that the surface crust on the tailings piles was sufficient to mitigate any existing risk.

2.4.1.4 Hardy Associates 1978

In 1978 Hardy Associates conducted a literature review and made recommendations on the use of sealants for stabilizing the tailings piles (Hardy Associates, 1978). Hardy Associates identified chemical treatment as the preferred option for stabilization of the tailings piles. The report concludes "the application of chemicals would form a durable crust which would minimize or eliminate water erosion."

2.4.1.5 Golder Associates 1980

In 1980 Golder Associates reported on channel closure monitoring at Clinton Creek and Wolverine Creek (Golder Associates, 1980).

2.4.1.6 Hardy Associates 1984

In 1984 Hardy Associates reviewed the available monitoring data on movements of the tailings piles and recommended possible rehabilitation measures (Hardy Associates, 1984).

Hardy Associates noted a general increase in the mean annual rate of movement at the midslope position on the north lobe. The mean rate of movement in 1984 was reported at approximately 10 m/yr. Movements at the toe of the north lobe were also found to be increasing; the mean annual rate of movement at the time of the study was reported at 30 m/yr. Hardy Associates predicted a "major failure" of the north lobe within a "couple of years".

Rates of movement on the south lobe were found to be "relatively small" and "more or less constant". Maximum recorded rates of movement were reported at approximately 6.0 m/yr. Hardy Associates reported that "these downslope movements will continue unless more toe support than presently in existence is provided."

Hardy Associates recommended five possible measures to mitigate the impacts of the tailings piles on Wolverine Creek:

1) Construction of a coarse rock drain;

2) Construction of a hydraulic tunnel to convey Wolverine Creek around the tailings piles;

3) Placement of corrugated steel pipes to convey Wolverine Creek through the tailings to the existing spillway;

4) Continued monitoring and maintenance;

5) Construction of a dam at the toe of the south lobe.

Hardy Associates concluded -

> "We do not consider the current program of inspection and unspecified maintenance to represent the most practical strategy for controlling erosion of the tailings. This approach could lead to a situation similar to Clinton Creek, i.e. long channel, experiencing retrogressive erosion cut through unstable and highly erodible material."

2.4.1.7 Cassiar Mining Corporation 1985

In 1985 Cassiar Mining Corporation reported the results of asbestos monitoring from Clinton Creek, Wolverine Creek, Fortymile River and Yukon River (Cassiar Mining Corporation, 1985). Results were presented for the years 1978 to 1985. Results for all sample points immediately downstream of the influences of the waste rock and tailings piles were extremely variable and did not exhibit any clear temporal trends. The results of the station on Wolverine Creek downstream of the south lobe, for example, varied from 3.3 x 10^6 fibres/litre to 730,676 x 10^6 fibers/litre over the eight year period of record. The results of samples taken upstream of the mine and from Fortymile River and Yukon River were significantly lower and less variable.

2.4.1.8 Klohn Leonoff 1986

In 1986 Cassiar commissioned Klohn Leonoff Consulting Engineers Ltd. to develop an Abandonment Plan for Clinton Creek Mine. A copy of this document was not available for this review.

2.4.1.9 Geo-Engineering 1986

Geo-Engineering conducted an assessment of the 1986 Klohn Leonoff Abandonment Plan for Clinton Creek Mine (Geo-Engineering, 1986). The results of this assessment are summarized in a 1986 letter report sent to Mr. Jack Nickel, Regional Manager, Indian and Northern Affairs. Geo-Engineering predicts that the waste rock and tailings piles are likely continue to move downslope and deposit materials in Clinton Creek and Wolverine Creek valleys. The continued downslope movement of the respective masses is expected to continue to result in modification, erosion and consequent sediment deposition to Clinton Creek, Wolverine Creek and downstream watercourses.

Geo-Engineering concluded "it is our opinion that the submitted 'Abandonment Plan' represents an attempt to satisfy regulatory requirements. The future impacts on streams and the environment is [sic] believed to be undervalued."

2.4.1.10 Klohn Leonoff 1987

In 1987 Klohn Leonoff carried out an assessment of the hazard to human lives presented by the waste rock dumps and tailings piles at Clinton Creek. The study was carried out in response to concerns expressed by DIAND over the 1986 Abandonment Plan.

Klohn Leonoff found that the Clinton Creek impoundment does "not present a flood hazard to human life." Additionally, "the tailings piles are ...not considered to represent significant hazards to human life." Although it was recognized that mass movement of the waste rock and tailing piles will continue to block Clinton Creek and Wolverine Creek and cause impoundment, it was concluded that the impacts of breaching, and subsequent downstream flooding and sedimentation, would be limited.

The Klohn Leonoff report also identifies potential strategies for lowering water levels in Hudgeon Lake. None of the strategies considered offered an advantage over existing conditions and the potential for lowering water levels was considered limited because lowering the lake level would remove toe support and reduce the stability of the waste rock dump.

2.4.1.11 Stepanek and McAlpine 1992

Stepanek and McAlpine examined the stability of the waste rock and mine tailings dams (Stepanek and McAlpine, 1992). They found that the probability of failure for the waste rock dam (Clinton Creek) was low while the probability of failure of for the tailings dam (Wolverine Creek) was high. They found that the "combined effect of flood conditions and breach of a channel blockage may present a hazard to human life."

Stepanek and McAlpine's investigation of the waste rock pile reports that the horizontal rate of movement had decreased from approximately 1.2 m/yr in 1978 to 0.3-0.6 m/yr in 1985. The report concludes that "as long as the armored section of the outlet channel remains intact, the probability of a sudden failure of this landslide dam is believed to be low." However, Stepanek and McAlpine also note that the channel armor has not been challenged by a major flood event and that retrogressive erosion is in progress.

The rate of movement of the south lobe of the tailings pile was estimated at 5-10 m/yr. "The tailings pile remains unstable, the displacement of the creek upstream from the spillway continues and additional temporary blockages have occurred." "The probability of a breach failure …is rated as high."

2.4.1.12 Geo-Engineering 1995 and 1996

Geo-Engineering conducted a series of site visits and assessments in 1995 and 1996 (Geo-Engineering, 1998).

Evidence of ongoing movement of the Clinton Creek and Porcupine Creek waste rock piles was observed. No significant changes in the armored portion of Clinton Creek channel were observed since their last inspection in 1992. The north and south banks of the creek channel downstream of the armored reach were observed to be unstable.

The north lobe of the tailings pile appeared to be less active than in 1992. However, both the north and south lobes of the tailings piles continued to move downhill at a "significant" rate. Continued erosion of the bedrock forming in the east side of Wolverine Creek was noted. Periodic temporary blockages of Wolverine creek were evident and appeared to be increasing in frequency. The armored spillway was functioning as designed.

2.4.1.13 Geo-Engineering 1997 and 1998

Geo-Engineering conducted a series of site visits and assessments in 1997 and 1998 (Geo-Engineering, 1998).

Evidence of continued movement of the Clinton Creek and Porcupine Creek waste rock piles was noted in 1997 and 1998. Indications of continued movement of the tailings piles were also observed.

A significant flood event occurred shortly before the 1997 site visit and resulted in decreased stability of Clinton Creek. The flooding largely destroyed the channel armor and weir structures. Lateral erosion and down cutting triggered "extensive" sloughing of channel banks downstream of the armored reach. The lake outlet was widened and a previously covered culvert was exposed. Geo-Engineering noted -

> "The Clinton Creek channel degradation, in the section along the toe of the rock waste dump, appears to be more significant than that predicted in Klohn Leonoff's 1987 report for a large flow event. However, no visible acceleration of dump movement was noticed at the time of the site visit."

Geo-Engineering concludes that the impact of the 1997 flood and ongoing gradual degradation have increased the risk of breaching of Hudgeon Lake.

The flood event did not impact Wolverine Creek with as much intensity. The creek channel along the toe of the south lobe was widened and the toe of the lobe eroded and steepened. This resulted in widespread sloughing of the face of the south lobe tailings pile.

Ongoing gradual degradation of Clinton Creek and Wolverine Creek stream channels was observed in 1998.

2.4.2 Biological Assessments

2.4.2.1 Fisheries and Environment Canada 1977

In response to concerns by DIAND and citizens of Clinton Creek, Fisheries and Environment Canada conducted an aquatic environmental quality survey in 1974 and 1975 (Fisheries and Environment Canada, 1977). Nine stations were established on Clinton Creek, Wolverine Creek and Fortymile River for the purposes of water quality and biological sampling. Water samples were collected for chemical analysis, asbestos fiber analysis, toxicity bioassays and gill tissue histopathalogical analysis. Benthic surveys and artificial substrate samplers were used to survey aquatic invertebrates. Fish populations were sampled with an electro-fisher.

Elevated levels of calcium, magnesium, iron, manganese and potassium were observed in Clinton Creek and Wolverine Creek. The concentrations were not considered high enough to be harmful to aquatic organisms.

Asbestos fiber analysis indicated that concentrations of fibers in Hudgeon Lake were higher than Fortymile River and other background levels reported. The mean length of asbestos fibers in Hudgeon Lake was also found to be significantly longer than normal fiber lengths.

Toxicity bioassays found that the water samples were "non-toxic at 100% concentration over 96 hours". "Subsequent bioassays were carried out for 8 and 16 days and were also "non-toxic".

The study showed reduced abundance and diversity of benthic invertebrates in the vicinity of the waste dump and tailings pile blockages. No aquatic invertebrates were observed a station four, immediately downstream of the south lobe blockage on Wolverine Creek. The authors attributed these observations to the negative impacts of the waste dump and tailings pile on aquatic habitat.

The electro-fishing survey failed to detect the presence of fish in Clinton Creek upstream of Hudgeon Lake or at the two upper sample stations in Wolverine Creek. The remaining stations on lower Wolverine Creek, Clinton Creek below Hudgeon lake and on the Fortymile River were "well populated with various species of fish. The most numerous...were the Longnose Sucker (*Catosomus catosomus*) and the Arctic Grayling *(Thymallus arcticus*)."

The results of the histopathological assessment identified elevated occurrences of separation of the lamellae epithelium in the experimental fish. This disorder became more prevalent with greater exposure time but fish recovered substantially following exposure. Experimental and control fish both displayed signs of hyperplasia and aneurysm in gill tissue. The ecological significance of the observed disorders was not quantified.

2.4.2.2 E.V.S. Consultants 1981

A study commissioned by Cassiar in 1980 (EVS Consultants Ltd., 1981) examined the effects of the mine waste dump and tailings on the fishery resource and in-stream habitat of Clinton and Wolverine Creeks. Extensive inventories of indigenous fish stocks were completed in September of 1980 using electro-shocking, beach seining and minnow trapping along various portions of Clinton Creek from Hudgeon Lake downstream to its confluence with Fortymile River. This was also supplemented by food source assessments using invertebrate drift samples (e.g., *Daphnia* sp.) in the upper section of Clinton Creek, as well stomach content analysis of some graylings from the creek and Hudgeon Lake.

The EVS report concluded that all sections of Clinton Creek provided suitable habitat utilized by healthy, representative populations of Arctic Grayling, juvenile Chinook salmon, and sculpins. The upper section below Hudgeon Lake, particularly, was identified as optimal stream habitat based on the large biomass of invertebrates and graylings found there. A 0.5 km section of the creek immediately downstream from the mine was noted to be detrimentally impacted from the outwash of waste rock into the streambed. Based on the lack of reported adverse affects on fish from aquatic asbestos contamination, EVS concluded that any fisheries resource loss had more likely resulted from physical destabilization and siltation of the streambed habitat than the toxicity of asbestos fibers. It was noted, however, that "net gain or loss of fisheries resources could not be defined by the present study"..

The EVS study did not detect any fish in Wolverine Creek. EVS concluded that the character of the streambed (washed tailings) and the extremely varied flows in Wolverine Creek resulted in the destruction of any formerly present fish habitat. Additionally, road culverts were observed to impede fish passage into Wolverine Creek.

The EVS report also reviewed the hazard and environmental risk associated with the ingestion of asbestos fibers in drinking water supplies derived from the Forty Mile River watershed. The study noted a lack of data supporting the ecological and human health effects of asbestos fibers in water and cautioned that more information is required to reach definite conclusions. Based on current understandings, EVS suggested that the detrimental effects of high asbestos fiber concentrations on aquatic communities would be minimal unless the fiber concentrations lead to habitat degradation or eutrophication. The human health risk was estimated at "a low level of hazard over a 70 year lifetime of ingestion."

2.5 Historical Timeline of Clinton Creek Mine

A summary of information presented in this chapter is provide in a historical timeline below:

→ 1967 Cassiar Asbestos Corporation Ltd. commences mining operations.

→ 1974 Failure of Clinton waste rock dump, impoundment of Clinton Creek and creation of Hudgeon Lake.

Failure of the south lobe tailings deposit and impoundment of Wolverine Creek.

The Yukon Territory Water Board issues a water license to Cassiar Asbestos Corporation Ltd. for the removal of water from and deposition of sewage to the Forty Mile River for the purposes of serving the Clinton Creek town site.

→ 1977 The last of the waste rock material is consigned to the waste rock dumps.

→ 1978 The Yukon Territory Water Board issues a water license to Cassiar Asbestos Corporation Ltd. for the operation of the mill site.

Cassiar Asbestos Corporation Ltd. ceases mining operations and removes the main sections of the concentrator, most mining equipment and the primary structures from the town site and auctions off the mill buildings and town site.

Cassiar Asbestos Corporation Ltd. constructs a rock-lined outfall channel and weirs to convey Wolverine Creek over the south lobe tailings deposit and terraces both the south and north lobe tailings deposits to increase stability.

Progressive failure of the north lobe tailings deposit begins.

→ 1981 Cassiar Asbestos Corporation Ltd. installs culverts and an apron at Hudgeon Lake outflow and constructs rock weirs and channel armoring in Clinton Creek.

→ 1982 Clinton Creek escapes armored channel during freshet and undercuts north valley wall.

The Yukon Territory Water Board water license for the mill site expires.

→ 1983 The Yukon Territory Water Board extends the water license for the mill site until 1987 to maintain a regulatory basis for achieving satisfactory mine abandonment.

→ 1984 Cassiar Asbestos Corporation Ltd. reconstructs channel armoring in Clinton Creek.

→ 1985 The north lobe tailings deposit mass reaches and impounds Wolverine Creek.

→ 1986 Cassiar Mining Corporation Ltd. submits an abandonment plan for the Clinton Creek mine to the Yukon Territory Water Board.

→ 1987 The Yukon Territory Water Board holds public hearings on the abandonment plan and subsequently recommends acceptance of the plan and extension of the water license. The Water Board also recommends that the $400,000 security bond posted by Cassiar at the time of the original license application be retained to establish a monitoring and risk management plan.

The Minister of Indian and Northern Affairs refuses to sign the proposed water license amendment.

The water license expires and DIAND retains the bond.

→ 1988 A Minesite Management Plan is developed to serve as a basis for an agreement on the ongoing monitoring and risk management activities to be undertaken by Cassiar and DIAND. DIAND holds negotiations with Cassiar and reaches a verbal agreement that Cassiar would address the requirements outlined in the Minesite Management Plan in return for the bond.

Cassiar Mining Corporation Ltd. removes the primary and secondary crushing units from the crusher building complex at the mill site.

→ 1989 Cassiar Mining Corporation Ltd. erects a series of warning signs and undertakes additional clean up of the abandoned mine site.

Cassiar requests that the bond held in association with the expired water license be returned. DIAND responds that there are outstanding issues and the matter is referred for legal review.

→ 1991 Cassiar Mining Corporation Ltd. has been bought by Princeton Mining Corporation Ltd.

DIAND and Princeton meet in September and the meeting is followed up with a letter from DIAND outlining the work required in return for relinquishment of the bond. Princeton provides no written agreement.

Princeton undertakes further remedial activities at the Clinton Creek site and requests that DIAND return the bond.

→ 1992 DIAND staff prepares a briefing note recommending that the bond be returned to Princeton.

→ 1997 A significant flood event largely destroys the channel armoring and weir structures in Clinton Creek.

3. METHODS

3.1 Overview of Field Investigations

A Site Reconnaissance Survey was carried out on August 10, 1998 to provide information and facilitate the preparation of the Site Investigation Work Plan. The reconnaissance team included Brett Hartshorne (DIAND, Waste Management), Matt Dodd (Royal Roads) and Ken Skatfeld (UMA Engineering). Following this a work plan was developed and presented to the DIAND Project Authority prior to the commencement of the field Investigation program.

The field investigation program was conducted from September 9 to 14, 1998. The team included P. Roach (DIAND), M. Dodd and B. Dushenko both of Royal Roads, and W. R. Rick (fisheries resources). Components of the field program included:

- Measurement of the bathymetry of Hudgeon Lake and hence water volumes;
- Collection of samples for the geochemical characterization of tailings and waste rock deposits, especially with regard to asbestos, metal and metalloid concentrations;
- Sampling of water, sediment and fish from Hudgeon Lake and along Clinton Creek, downstream of the mine to the Fortymile River to assess waste materials redistribution;
- A quantitative assessment of the terrestrial habitats using vegetation surveys in areas directly and indirectly affected by the mine tailings and/or waste rock;
- Collection of representative plant samples and archived for future contaminant analysis pending the analytical results from the accompanying soil samples; and
- An assessment of site use by potential mammalian and avian wildlife.

3.2 Measurement of Bathymetry of Hudgeon Lake and Water Volumes

A Lowrance X-15 Echo Sounder (McQuest Marine Sciences Ltd.) was attached to a small Zodiac™ and used to examine the bathymetry of Hudgeon Lake. One longitudinal and five transverse transects were run with the Zodiac cruising at constant speed to obtain a paper record of echo sounder profiles. The transects are indicated on Figure 3.1. Depths to the bottom of the lake along the transects were obtained from the echo sounder profiles and the data was subsequently used to manually calculate the lake volumes.

3.3 Inventory and Habitat Assessment of Aquatic and Riparian Ecological Receptors at Risk

The objectives of this task were to -

- Establish current baseline conditions of terrestrial and freshwater (primarily fish) habitat in areas affected by mine tailings and waste rock in Clinton Creek and compare these with previous reported conditions where available (i.e., EVS, 1981);
- Identify comparative background conditions at another reference site which can be used to assess the current degree of impact from the site in affected areas; and
- Pinpoint specific ecological indicators which could be used as part of the above assessment, as well as identifying potential ecological receptors at future risk (particularly fisheries resources) for both the ecological and engineering risk assessments.

To achieve these objectives, the ecological survey consisted of an aquatic component focusing on fisheries resources and productivity, as well as a terrestrial habitat component examining vegetation reestablishment and slope stabilization, and terrestrial receptors at risk within the area of influence of the mine.

3.3.1 Aquatic (Fisheries) Habitat

This component of the ecological assessment followed much of the same methodology, including the sampling time (September – with similar meteorological conditions), for fisheries impact assessment employed by EVS (EVS 1980). Although the sampling time and methodology used during the 1980 investigation may not have been the most ideal for the fisheries habitat under study (Al von Finster, HEB DFO, pers. comm., 1999), a similar approach was used here, where possible, in order to facilitate a direct comparison of informationand data between the two studies. This allowed for a more effective assessment of relative temporal as well as spatial changes in fishery resources since 1980.

Following a reconnaissance survey of Clinton Creek and its tributaries including Bear, Porcupine and Eagle Creeks; environmental sampling stations were set up in nine study zones comparable to those utilized in 1980 along the Clinton Creek drainage using Hudgeon Lake outlet as a starting point. Two areas along Forty Mile River, (one upstream and a second downstream of the confluence of Clinton Creek) and one reference zone were also chosen. Thus nine study zones were selected as follows:

- Zone 1: Just below (30 m SE) of the Hudgeon Lake outlet.
- Zone 2: 1.5 to 3.5 km downstream of Hudgeon Lake, including confluence of Wolverine Creek.
- Zone 3: 3.5 to 6 km downstream, including confluence of Eagle Creek.

- Zone 4: 6 to 7 km downstream.
- Zone 5: 7 to 8 km downstream, identified but inaccessible for sampling by EVS.
- Zone 6: 8 to 9.2 km downstream, above the creek entrance to Forty Mile River and the old town site.
- Zone 7: Fortymile River, downstream of Clinton Creek confluence.
- Zone 8: Fortymile River, upstream of Clinton Creek confluence.
- Zone 9: Mickey Creek – reference location, 1 km upstream (SE) of its confluence with Fortymile River (not previously sampled by EVS) with similar biophysical habitat characteristics.

The sampling zones along the watershed are presented in Figure 3-2.

3.3.1.1 Minnow Trapping

Sets of 3 or 4 standard minnow traps for fry were set up in each of Zones 1 to 6. A set of traps were also set at Zone 9 (Mickey Creek, the reference location). The traps were baited with previously-frozen salmonid roe wrapped in a small piece of nylon secured to the trap frame. General biophysical observations (i.e., stream dimensions, flow, riparian vegetation, and substrate type) were conducted and recorded in each sampling zone, in addition to measurements of pH, conductivity and temperature as part of the water and sediment sampling program. Each zone was fished for an average period of 28 hrs. Although the 1980 methodology may not have been the most ideal for capturing slimy sculpin and grayling fry (Al von Finster, HEB, DFO, pers. comm., 1999), relative catch information for different fry species between the 1980 and current (1998) study using the same methodology still made for a valuable comparison. An average of 10 fry samples (where available) was collected from each of the traps and preserved for later analysis. Harvested samples were measured for total length and frozen for later chemical analysis. Gill lamellae were extracted from a subset of these (3-4 specimens) and placed in 5% buffered formalin solution for later histopathological analysis as required.

3.3.1.2 Gillnetting

Two nylon gillnets (2.5 and 10 cm mesh sizes), 20 m in length each were placed in approximately 3 m of water in Hudgeon Lake above the mouth of Clinton Creek in similar positions to those used in the earlier EVS investigation. The two nets were placed in parallel to one another, approximately 10 m apart, in an east-west orientation transecting the southeast end of the lake and roughly 20 m north from the mouth of the creek. The nets were held in place using floats and weights that were secured at the upper and lower corners, respectively. Unfortunately, a gillnet in the "intermediate" mesh size range used in the earlier EVS study (6.4 cm) was unavailable to the field team which would have been ideal for capturing young adult grayling in the lake (Al von Finster, HEB, DFO, pers. comm., 1999), if present. The two nets used were left for a period of two days and checked daily. No fish were obtained in either of the nets over this sampling period.

3.3.1.3 Electrofishing

Electrofishing was conducted on a preliminary test basis at location DS2 located just above the two-way wier location (Zone 6) above Forty Mile River in the 1980 EVS study. No stop nets were used in up- or downstream positions during this exercise as a consequence. The small number of captured fish (fry) were harvested and frozen for later analysis, as required.

3.3.1.4 Invertebrate Drift Samples

Benthic traps (surber samplers) were placed in Clinton Creek in Zone 1, just below Hudgeon Lake and in the vicinity of the minnow trap reference location in Mickey Creek to obtain a preliminary estimate of productivity. Traps were set in midstream and left for a period of 24 hours. Samples were collected and frozen for later analysis; a sub-sample was stored in buffered formalin for later sorting/identification.

3.3.1.5 Plankton Samples

Samples were obtained using plankton cone-nets at the mouth of Hudgeon Lake and 500 km to the NE near the lake's centre. Nets were lowered and raised through the water column at 1 and 8 m depths. Samples were frozen for later analysis and a sub-sample placed in 5% buffered formalin solution.

3.3.2 Terrestrial Habitat

A quantitative assessment of the terrestrial habitats was conducted using ground cover vegetation surveys in representative areas directly and indirectly affected by the mine tailings or waste rock. Coverage, abundance and inventory of plant species in a series of 1 m^2 survey quadrats was measured in conjunction with soil/sediment sampling. A total of 27 quadrats were surveyed as follows;

- 12 quadrats surveyed at sample locations in the waste rock deposit areas;
- 10 quadrats surveyed in the Mill site and tailings pile (North and South lobes); and
- 5 quadrats surveyed at reference sample locations:

Samples of the most frequently occurring plant species in the quadrats, *Hordeum jubatum* (wild barley or squirrel tail grass), were collected from each quadrat, where available, and archived for future contaminant (metals) analysis pending the analytical results from the accompanying soil samples.

An assessment of site use by potential mammalian and avian wildlife was also conducted on a qualitative basis using observations, sightings and related information on the area from literature sources.

3.4 Geochemical Stability of Waste Rock and Tailings Materials - Analysis of Potential for Metals Input.

The objective of this task was to characterize the geochemistry of tailings and waste rock deposits, especially with regard to metal/metalloid concentration and define waste material 'fingerprint' based on relative metal/metalloid and asbestos composition.

3.4.1 Soil Sampling Protocol

The soil samples were collected, stored and transported under conditions that ensured sample integrity prior to laboratory analysis. The general protocols presented in Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites (CCME EPC-NCS62E, Winnipeg, Manitoba, December 1993) was used. In general, the top 10 cm of the substrate was removed using a dedicated stainless steel scoop and placed into 250 mL glass jars. Samples earmarked for asbestos analysis were placed into 25 mL glass scintillation vials. The scoops used were pre-cleaned by washing with Sparkleen™, rinsing with deionized-distilled water and followed by a solvent rinse. They were then baked at $400^{O}C$ for 4 hr and wrapped in baked aluminum foil to preclude contaminants. The sample containers were labeled and placed in coolers. Sample information was recorded on the chain-of-custody forms. The physical characteristics of each sample and photographs of sampling locations were taken.

A shovel was used to obtain a shallow sub-surface profile at two of the sampling locations.

3.4.2 Summary of Soil Sampling Program

Samples were collected to represent different substrate types noted on site on the basics of physical characteristics such as colour and grain size. Attempts were also made to obtain samples from drainage pathways and from all the different areas of the site. Sampling locations are shown in Figure 3.3. A summary of soil and sediment samples collected for analysis is given in Table 3-1. Detail description of sampling locations and substrate is given in Appendix A.

Table 3-1: Summary of Samples Collected to Characterize Metal and Asbestos Contents of Waste Rock and Tailings

Area	**Number of Samples Collected**	**Sample Designation**
Waste Rock	14	CLWR-1 to CLWR-14
Mill Site (Tailings Deposits)	13	CLMS-1 to CLMS-12, CLMS-14
Background	5	CLBK-1 to CLBK-4, CLMS-13
Total Collected	**32**	

3.4.3 Analytical Program for Soils

Soil samples were shipped to Analytical Services Laboratory (ASL), Vancouver, BC where they were analyzed for metals and metalloids. A subset of samples was analyzed for bulk asbestos content at North West Environmental Group Ltd., Victoria, BC. The analytical methods employed are presented in laboratory reports attached in Appendix C. Table 3-2 contains a summary of the analytical program

Table 3-2: Summary of Samples Analyzed to Characterize Metal and Asbestos Contents of Waste Rock and Tailings

Area	Number of Samples Analyzed	
	Metals	**Asbestos**
Waste Rock	9	5
Mill Site (Tailings Deposits)	8	8
Background	3	1
Total Analyzed	**20**	**14**

3.5 Evaluation of Downstream Waste Materials Redistribution using Chemical Tracers and Asbestos in Riverine Sediment Deposits

The objective of this aspect of the program was to evaluate the chronic re-distribution downstream of mine site materials using data on the concentration of asbestos and metals in sediments and water along the Clinton Creek watershed. To achieve this objective, water and sediment samples were collected from Hudgeon Lake, Wolverine Creek, Fortymile River and three reference locations.

3.5.1 Water Sampling Protocols

Grab surface water samples were collected using high-density polyethylene bottles. The bottle was held near the base and the neck plunged below the surface (25 - 40 cm). The jar was tilted such that the neck pointed to the water flow during filling. Samples were also collected into 50 mL disposable Evergreen™ polyethylene vials and the pH, conductivity and temperature were measured. Electrical conductivity measurements were performed with a Cole Palmer Model # 1481-60, which was calibrated with a 1413 µS standard solution while a Barnet Model 30 pH meter, calibrated with pH 7 and pH 4 standard solutions was used for the pH and temperature determinations. The pH, conductivity and thermal probes were rinsed with distilled water and wiped with Kimwipes™ after each determination.

Samples for asbestos analysis were placed into 1 L bottles that were pre-cleaned by washing with laboratory detergent (Sparkleen™) and rinsed with deionized-distilled water. They were then acid washed by immersing in dilute hydrochloric acid overnight and rinsed with deionized distilled water.

Samples earmarked for dissolved metals analyses were field filtered using disposable in-line 700 cm^2 x 0.45 μm membrane filter (Gelman Sciences). The filtered samples were placed into a 250 mL container and preserved with nitric acid. The sample for total metals analyses was collected directly into a 250 mL container without filtration and preserved with nitric acid. For inorganic non-metallic analytes, samples were placed into 500 mL jars.

All the labeled sample containers were placed into coolers and shipped to the analytical laboratory via Canadian Air Cargo. Chain of custody forms accompanied the shipment. A summary of the sampling program is given in Table 3-3.

3.5.2 Summary of Water Sampling and Analytical Sampling Program

A summary of the water sampling and analytical program is given in Table 3.3 below. Detail descriptions of sampling locations are given in Appendix A. The locations are also indicated on Figure 3.2.

Samples were analyzed at Analytical Services Laboratory for metals and inorganic non-metallic parameters (including nitrate, nitrite, bromide, chloride, fluoride, sulphate and total alkalinity). For asbestos analysis, samples were shipped to EMSL Analytical, San Mateo, California. Analytical methods used by both ASL and EMSL are included in the laboratory reports attached in Appendix C.

Table 3-3: Summary of Water Sampling and Analytical Program

Area	Number of Samples Collected	Number of Samples Analyzed				
		pH	Anions	Nutrients	Total Metals	Dissolved Metals
Hudgeon Lake	7	8	3	3	6	2
Clinton Creek	7	6	2	2	3	2
Mill Site	1	1	-	-	1	-
Wolverine Creek	4	4	2	2	2	-
Waste Rock Area	3	3	-	-	2	-
Fortymile River	2	2	1	1	1	-
Reference Creeks	3	3	2	2	2	-
Total	**27**	**27**	**10**	**10**	**17**	**4**

3.5.3 Sediment Sampling Protocols

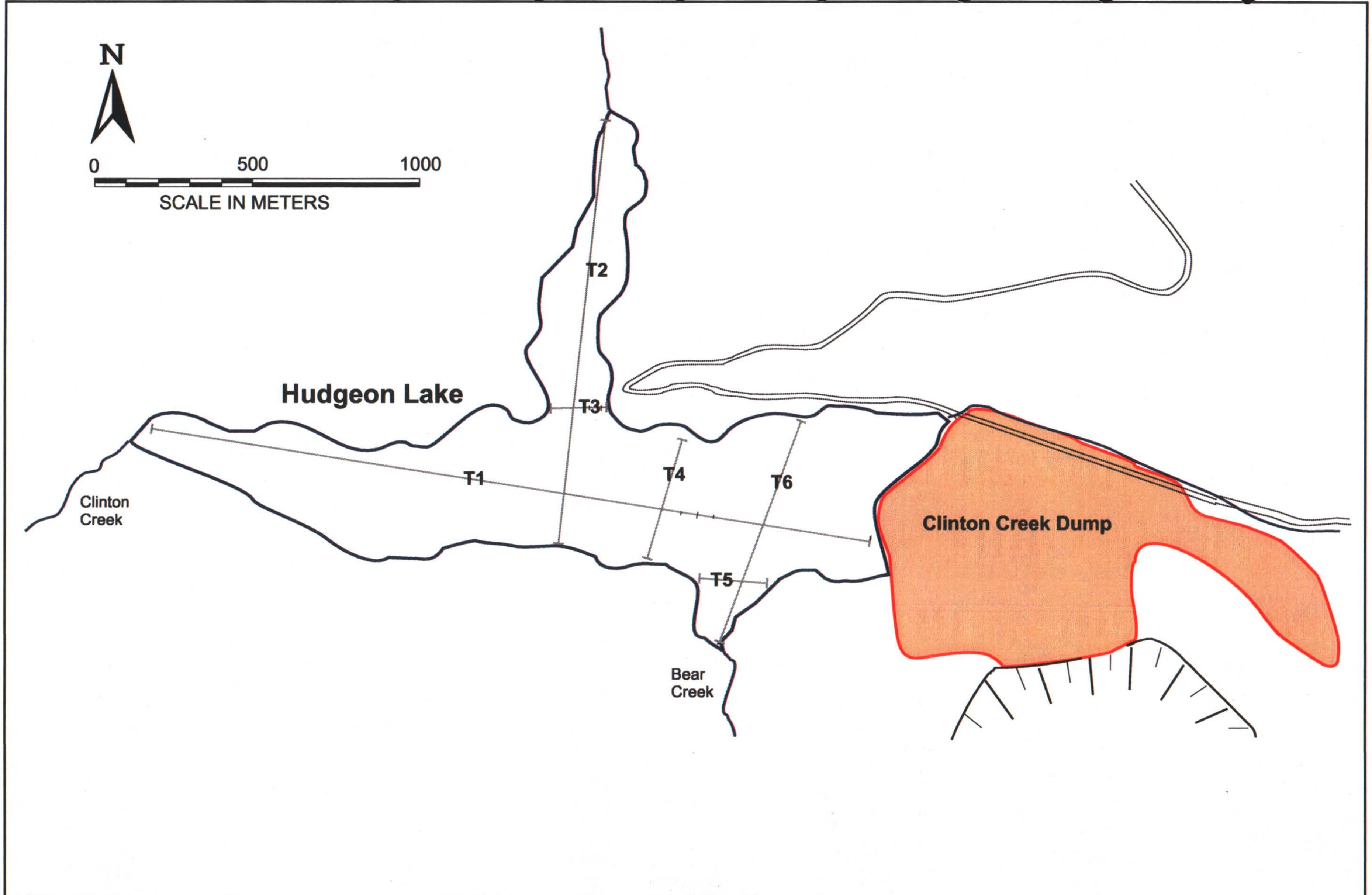
A Petite Ponar grab was deployed by hand from a Zodiac™ to obtain sediment samples from Hudgeon Lake. Sub-samples of the sediments were then placed into glass containers. Samples from Clinton, Wolverine, Eagle and Mickey Creeks, as well as the Fortymile River, were collected from shallow locations close to the shoreline. The top 5 cm of sediment within an area of 1 to 2 m from the shoreline was removed using pre-cleaned stainless steel scoops and placed into 250 mL glass jars. A number of samples were also placed into 25 mL scintillation vials for asbestos analysis.

3.5.4 Summary of Sediment Sampling and Analytical Sampling Program

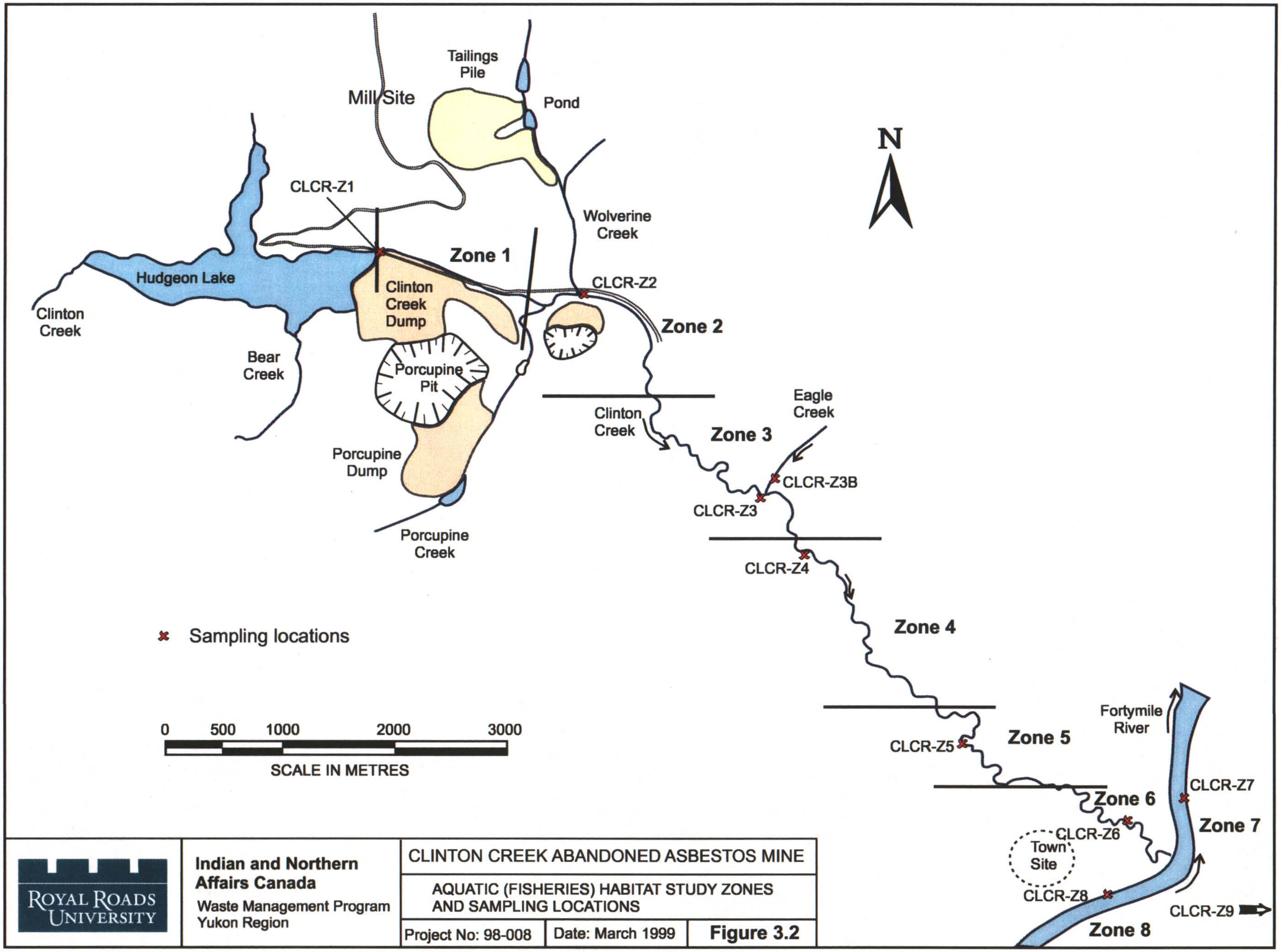
A summary of the sampling and analytical program is given in Table 3-4. Sampling locations are described in Appendix A and depicted in Figure 3.2. The sediment samples were analyzed for asbestos using procedures similar to those described for soils in Section 3.1.4 above.

Table 3-4: Summary of Sediment Sampling and Analytical Program

Area	Number of Samples Collected	Number of Samples Analyzed	
		Metal	Asbestos
Hudgeon Lake and Waste Rock	7	2	4
Clinton Creek	6	1	3
Fortymile River	2	1	2
Wolverine Creek	5	3	3
Reference Creeks	3	2	3
Total Collected	**23**	**10**	**15**



ROYAL ROADS UNIVERSITY	**Indian and Northern Affairs Canada** Waste Management Program Yukon Region	CLINTON CREEK ABANDONED ASBESTOS MINE HUDGEON LAKE BATHYMETRY TRANSECT LINES Project No: 98-008 | Date: March 1999 | **Figure 3-1**

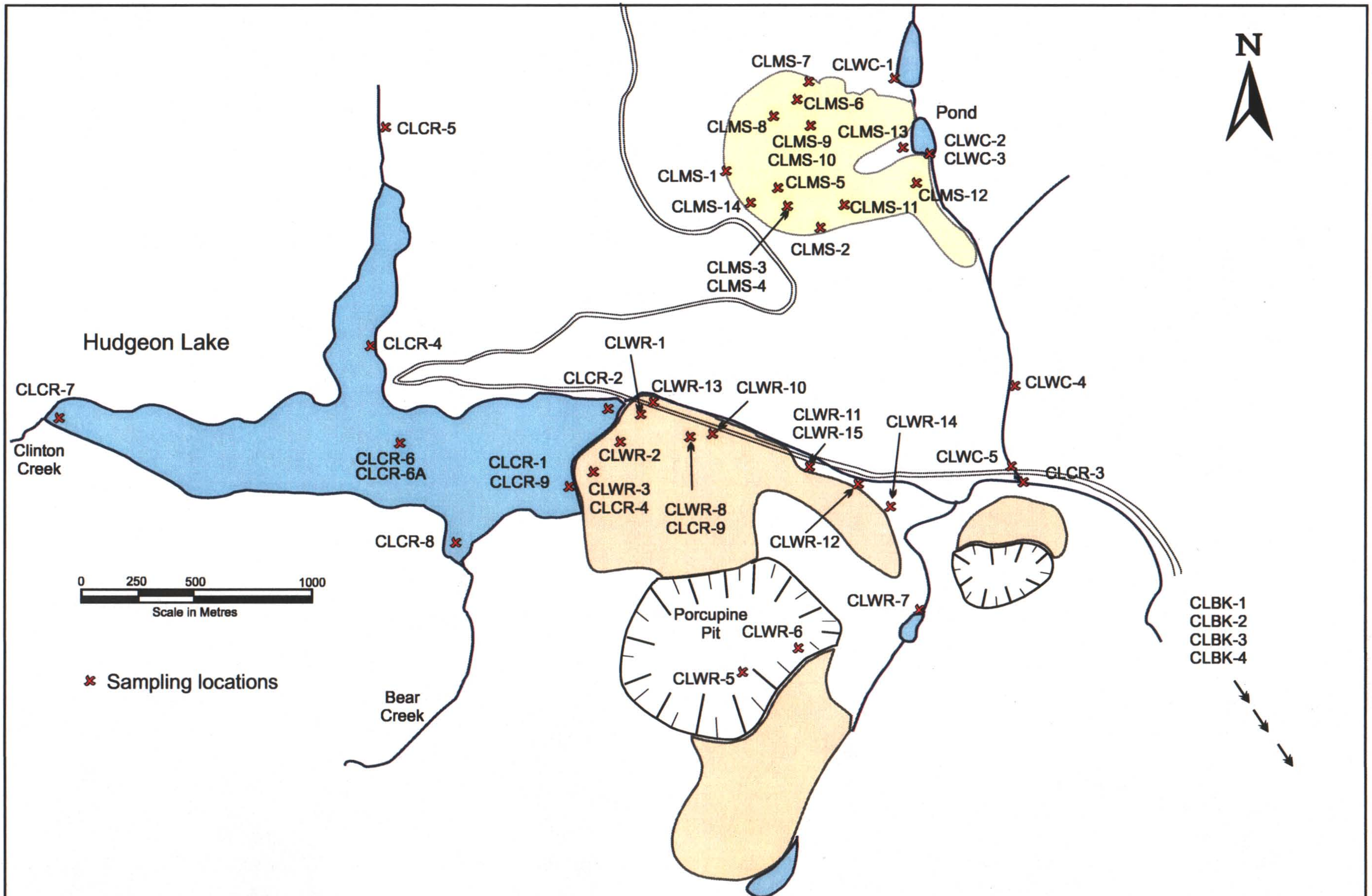


Indian and Northern Affairs Canada
Waste Management Program
Yukon Region

CLINTON CREEK ABANDONED ASBESTOS MINE

AQUATIC (FISHERIES) HABITAT STUDY ZONES AND SAMPLING LOCATIONS

Project No: 98-008 | Date: March 1999 | **Figure 3.2**



ROYAL ROADS UNIVERSITY

Indian and Northern Affairs Canada
Waste Management Program
Yukon Region

CLINTON CREEK ABANDONED ASBESTOS MINE

HUDGEON LAKE, WASTE ROCK AND MILL SITE/TAILINGS SAMPLING LOCATIONS

Project No: 98-008	Date: March 1999	**Figure 3.3**

4. RESULTS OF FIELD INVESTIGATION

4.1 Measurement of Bathymetry of Hudgeon Lake and Water Volumes

In 1978, the maximum water depth of Hudgeon Lake was approximately 26 m and the surface area was approximately 73 ha (Golder, 1978). The size of the waste rock dam blocking Clinton Creek was estimated to be approximately 0.8 km long and 50 m high (Stepanek and McAlpine, 1992).

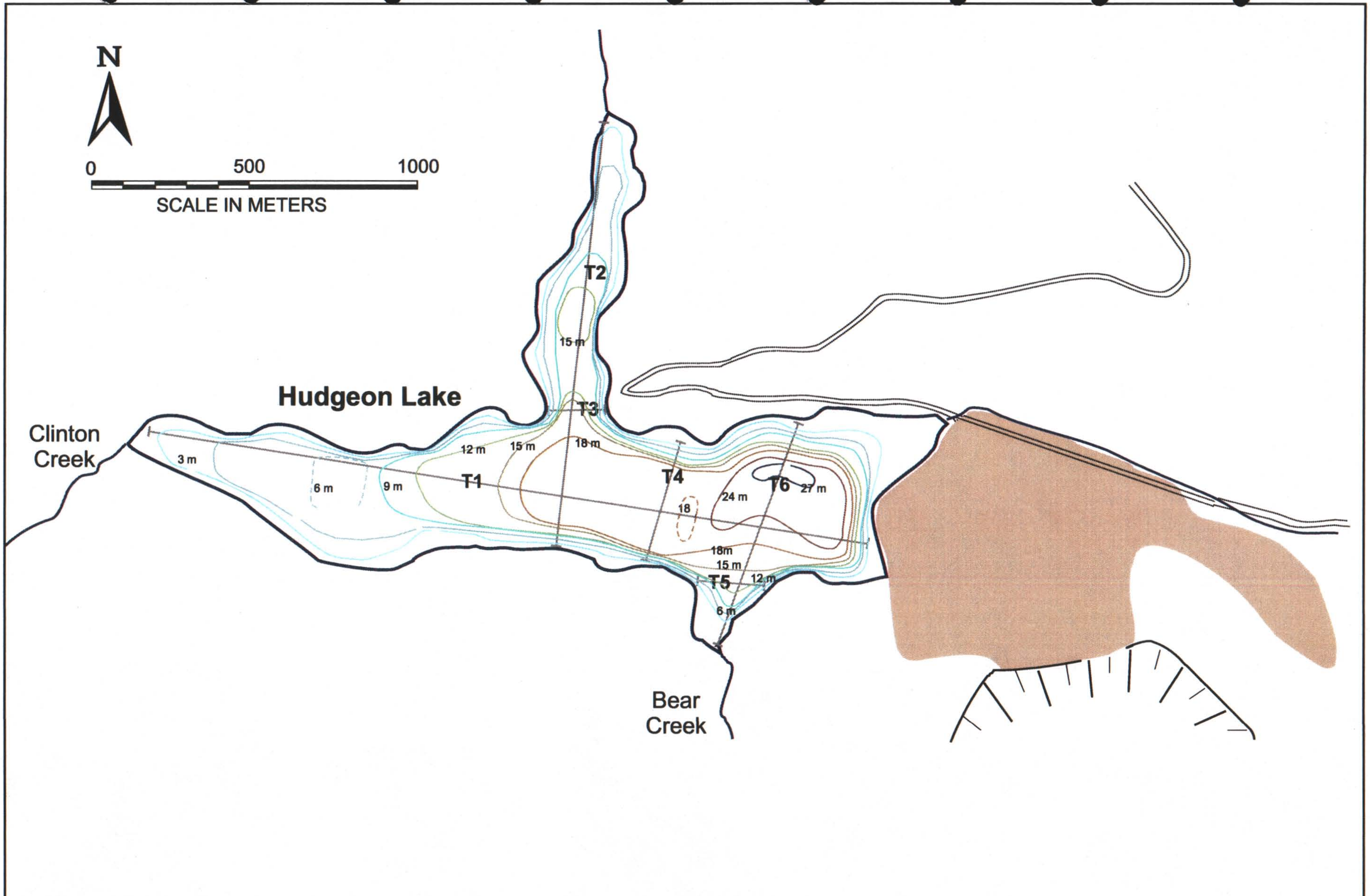
The reconstructed bathymetry of Hudgeon Lake from echosounder traces collected during this study is provided in Figure 4.1. The bathymetric interpolations were based on depth profiles along six transects. The shoreline was reconstructed from an aerial photograph taken in 1985. The hand-fitting techniques employed in re-constructing bathymetry undoubtedly introduced some inaccuracy in the estimates of depth at specific areas in the lake, as well as in volume estimates; however, the volume estimates are deemed to be accurate within ± 50%. This estimate notwithstanding, any modeling of downstream risks associated with water and sediment transport should include some sensitivity analysis around these lake strata volume calculations.

The present surface area of Hudgeon Lake is estimated at 115 ha (1.15 x 10^6 m^2), with a maximum depth of around 27 m, assuming that the depth transects traversed the deepest point in the lake. The total estimated volume of the lake at the time of sampling was 1.2 x 10^7 m^3.

As a pre-requisite to quantitatively estimating the risks of differing magnitudes of breaches of the waste rock blockage at the toe of Hudgeon Lake, the volume distribution function by lake depth was also plotted (Figure 4.2). The bathymetric contours shown in Figure 4.1 are provided at 3 m depth intervals. It is possible to estimate the volume of water - and suspended sediment (including asbestos fibres) - which would be released based on a breach in the blockage that lowered the lake level by 1 m, 5 m 10 m or any other height.

Examples of the echosounder traces for transect lines T6 and T4 are provided in Figure 4.3. The extent of in-filling of the lake bottom by sediments from the waste rock pile cannot be definitively assessed from the bottom profiles, but it is likely that the flatter portions of the lake basin areas represent poorly consolidated sediments from the combined inputs of waste rock slope failures and sediment transport from higher up in the water shed.

The bathymetry of Hudgeon Lake in the vicinity of the outflow will be an important determinant of the long-term stability of the impoundment and of the lake as a whole. This area, in retrospect, could have been surveyed for bathymetry more extensively; there is considerable uncertainty in the construction of depth contours in this area. A more extensive survey using a sub-bottom profiler would provide not only a more accurate picture of the bathymetry, but also of the stratification and consolidation of bottom materials.



Indian and Northern Affairs Canada
Waste Management Program
Yukon Region

CLINTON CREEK ABANDONED ASBESTOS MINE

HUDGEON LAKE BATHYMETRY

Project No: 98-008	Date: March 1999	Figure 4.1

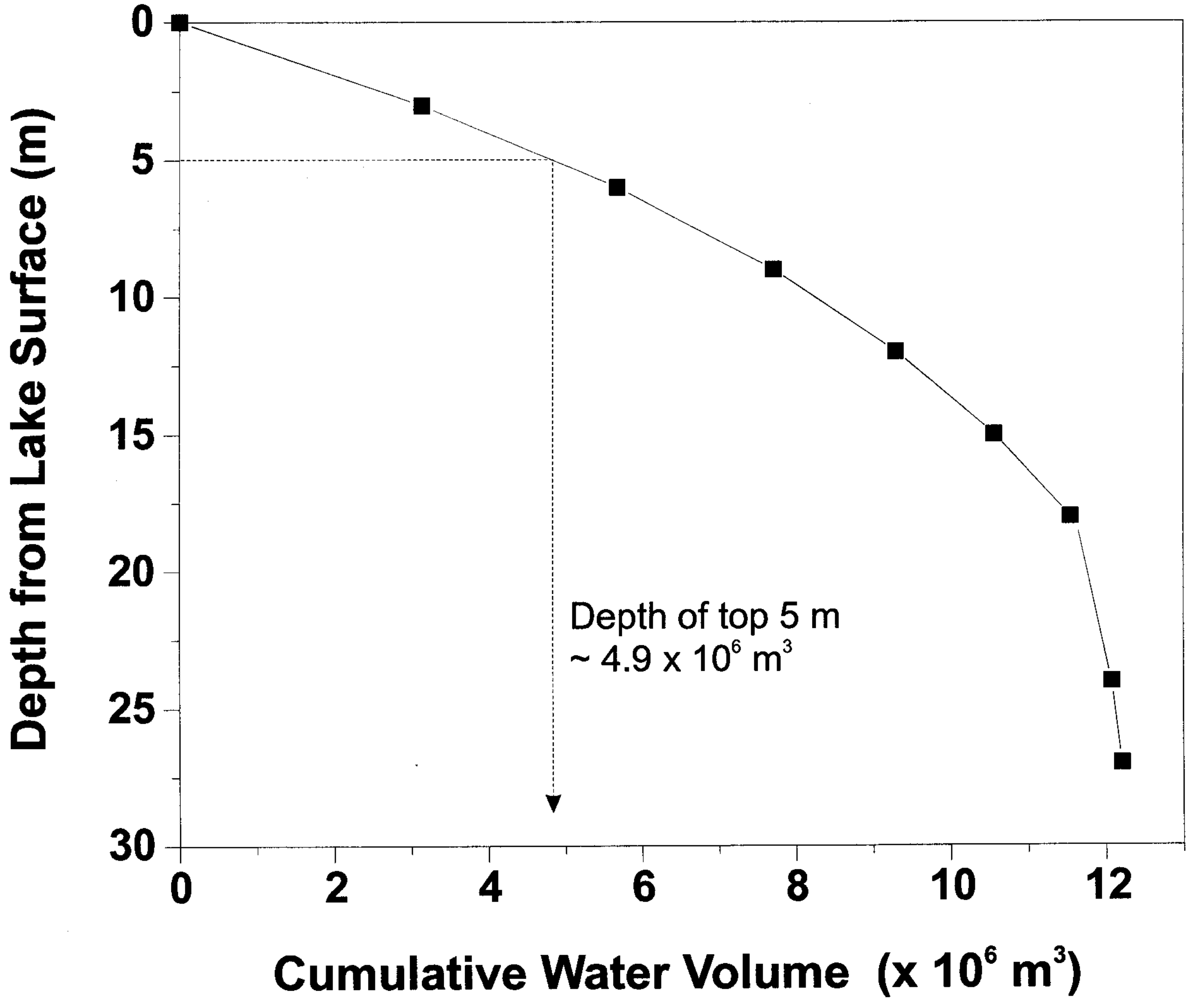
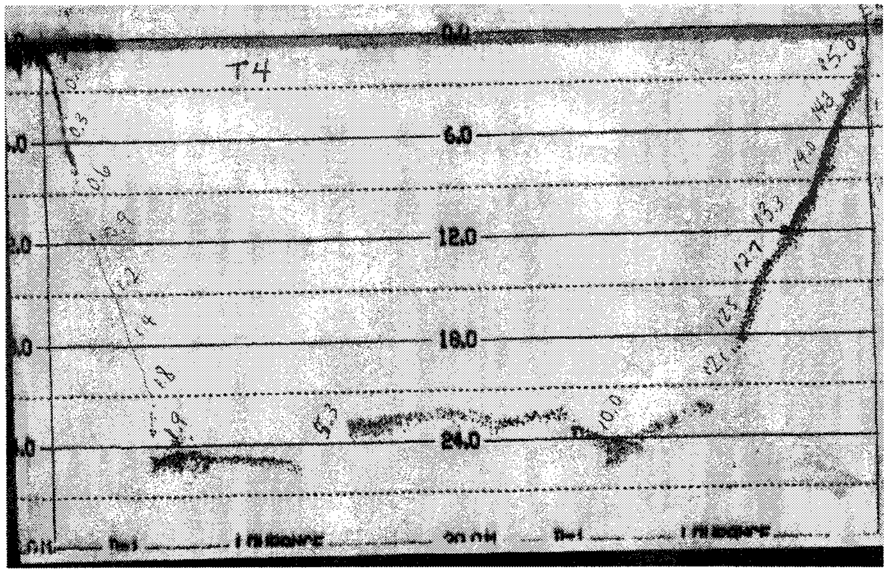


Figure 4.2: Lake volume distribution function for Hudgeon Lake.

Transect T4: N. to S.



Transect T6: S. to N.

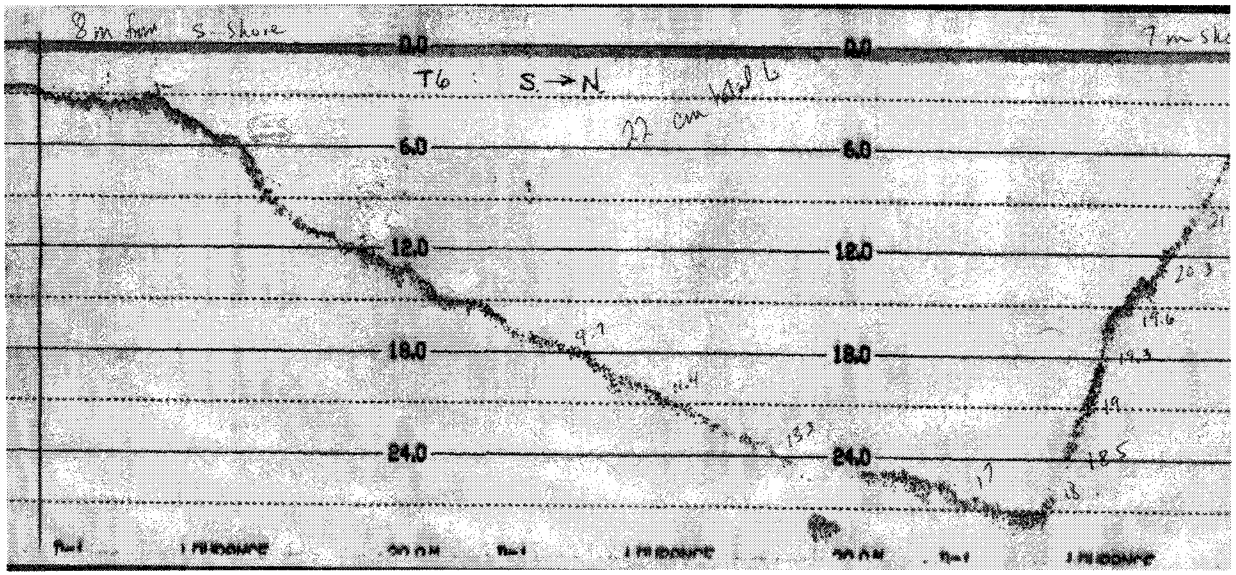


Figure 4.3: Representative Ecosounder Traces From Hudgeon Lake

4.2 Inventory and Habitat Assessment of Aquatic and Riparian Ecological Receptors at Risk

Considerable movement and shifting of the mine waste dump and tailings along with intermittent failures and erosion of the impoundments has occurred over the past 18 years since the EVS 1980 study was conducted (Northern Affairs, 1998). This has undoubtedly resulted in considerable biophysical changes to the Clinton Creek drainage area and accompanying stream habitats. It is also unknown whether potential metal contaminants resulting from the geochemical instability of the tailings have significantly affected the stream and terrestrial habitats over this time period.

A preliminary ecological habitat survey and analysis was conducted in the Clinton Creek drainage, therefore, to -

- determine whether any significant habitat changes have occurred over this 18 year period including changes to fisheries resources, and
- provide up-to-date information on potential ecological receptors which can be used in ecological risk assessments, as necessary.

Although much of the focus in previous studies has been on fisheries habitat, it was also important to gain an understanding of mining impacts to the terrestrial environment of Clinton Creek including slope-stabilizing vegetation which may influence substrate erosion (i.e., mine tailings, waste rock, stream banks) into the stream environment. The ecological survey, therefore, consisted of an aquatic component focusing on fisheries resources and productivity as well as a terrestrial habitat component examining vegetation reestablishment and slope stabilization within the area of influence of the mine.

4.2.1 Aquatic Habitat and Fisheries

4.2.1.1 Biophysical Habitat Quality.

Qualitative observations were made on fish habitat at each of the six zones designated for minnow traps including stream size, flow and gravel size. These observations are presented along with those from EVS in 1980 in Table 4-1 below. Descriptions made by EVS in 1980 concentrated on gross observations of habitat quality along the different creek zones, whereas observations by RRU focused more on discrete observations of the habitat in which the traps were specifically set. Observations by RRU also included stream volume (width and depth) and velocity estimates. Some nuances also occur in terms of differences between the two studies where traps were laid along the creek zones. Despite these differences, some trends over the years are apparent as discussed below. Water temperatures along the Clinton Creek during the time of sampling ranged from 4.3 °C in Zone 3 (near the confluence of Eagle Creek) to 7.7 °C in Zone 2 below the mine access bridge site. Water levels in the creek were moderate relative to its holding capacity as a result of precipitation in the region prior to the sampling program. Flow rates ranged from 0.7 to 1.5 m/sec. Conductivity in the waters of the Creek ranged from 133 μS at Zone 6 to 342 μS in Zone 5, with an average pH of 7.4.

Table 4-1: Inter-Study Comparison of Clinton Creek Biophysical Habitat Quality in Different Zones of Clinton Creek

Section/Zone	1980 (EVS) Descriptions	1998 (RRU) Observations
1	• Dominated by narrow, steep canyon with deep slots and holes adjacent to boulders and bed-rock. • Weirs constructed to contain slumping waste rock • No riparian vegetation due to bank erosion.	• Above canyon area, 40 below Hudgeon Lake: steep banks with many large boulders, no sign of weirs in lower portion. • Series of small side pools sheltered by bank undercuts and riparian vegetation including small trees (e.g., poplar, willow)
2	• Upper section consists of braided channels through washed waste rock • Little or no vegetation with unstable stream bed • Lower section consists of one channel with increased stream stability and some streamside vegetation (willows, brush, spruce)	• Course rock shoal along W bank at confluence with Wolverine Creek culvert • Rock bottom with gravel, cobble and small amount of sand • Narrow side channel 2 m N of confluence • Beaver dam ~ 100 m upstream causing overflows and flooding along banks • Riparian vegetation includes mixed poplar/willow/spruce with riparian vegetation • Channel 5 m wide x 1 m deep; average flow of 1.5 m/sec.
3	• Region relatively undisturbed consisting of gravel/cobble runs and riffles • Moderate gradient with occasional bedrock outcroppings creating faster water & rock debris • Stream very stable with abundant and varied streamside vegetation	• Confluence of Eagle Creek, backwater just to south • Coarse sand and pebble banks at confluence with gravel bottom (good spawning areas) • Lot's of riparian vegetation including birch, willow, sedge; small amounts of woody debris along W bank • Large pool leading into riffle area • Channel 6-10 m wide x 1-1.2 m deep; average flow of 1 m/sec.

Table 4-1: Inter-Study Comparison of Clinton Creek Biophysical Habitat Quality (Cont.)

Section/Zone	1980 (EVS) Descriptions	1998 (RRU) Observations
4	• Similar to Zone 3 with more gravel, longer runs with fewer holding areas and less bedrock • Unstable streambed during high water	• Steep ravine on both sides with predominantly undercut banks • Large rocks on streambed; dead trees along foreshore with few side pools • Riparian vegetation includes dense willow, poplar, spruce (further upslope), grass and moss along stream edge • Channel 4-5 m wide x 1 m deep; average flow of 0.7 - 1m/sec.
5	• Not observed - inaccessible	• Steep eroded slope along E side, rock bank along W side leading up to steep treed slope • Mostly riffling with few pools but lots of undercut bank • Banks surrounded by young poplar & birch, some grass and shrub along riparian zone • Channel 6 m wide x 0.5 m deep; average flow of 0.4 - 0.5 m/sec.
6	• Meandering with combination of deep holes, cut banks, and small runs • No bedrock, heavy streamside vegetation predominates, streambed is sand or fine gravel, some loose cobble in faster riffles between pools • Abundant holding areas, root wads and log jams • Streambed and bottom become unstable towards Forty Mile River confluence	• 70-100 m downstream from beaver dam just above forty mile crossing bridge, steep eroded banks in places • Cobble and gravel bed midstream with medium sand/silt along edges • Riparian vegetation dominant including willow, alder, birch and sedge • Channel 8m wide x 0.5 m deep; average flow of 1m/sec.
Reference Location (Mickey Creek)	• Not assessed	• I km upstream from south shore of Forty Mile River by road culvert • Gravel/pebble shoal along centre of creek, streambed coarse gravel and pebbles, pebble shore on W side, E bank undercut • Dense riparian vegetation right up to banks including mixed willow, birch and grasses • Channel 25 m wide x (average) 0.5 m deep; average flow of ~1m/sec

Slumping and erosion of waste rock in *Zone 1*, noted in 1980, has continued. Some riparian vegetation, nevertheless, has begun to re-establish since this time particularly in the upper portion of the zone near Hudgeon Lake. Erosion of the banks in this upper portion has resulted in undercuts forming a series of small pools. The narrow canyon in the lower portion has cut even deeper into the waste rock leaving steep scree slopes with exposed faces of bedrock in some places and swift currents (Photograph 4.1). No evidence of the weirs mentioned in 1980 was visible. The establishment of isolated pockets of shrub vegetation was also noticed here. The high energy waters of the canyon likely serve as a barrier to most young fish from the lower portions of the Creek. This lower area contains limited refugia for fry and the high energy water there likely continues to be a barrier to access from lower portions of the creek.

Braided channels previously mentioned in the upper portion of *Zone 2* seemed to have converged into one main stream. This may partly be due to the establishment of a beaver dam causing flooding of the stream banks in this area (Photograph 4-2). The streambed seems to have stabilized considerably since 1980, although a few pebble shoals do occur in the area. Riparian vegetation is considerably more abundant in the upper and lower portions of the zone with the re-establishment of a young mixed poplar, willow and spruce forest in the area.

In *Zone 3*, habitat conditions appear to be relatively unchanged since 1980 with a healthy mix of riparian vegetation and mixed willow forest. Flows are generally slower in this area owing to the winding nature of the creek and wider channels resulting in large pools intermixed with riffle areas. Mixed gravel and coarse sand dominates the stream bottom in this area which, when combined with other features above, may represent good salmon spawning habitat.

Runs mentioned in the 1980 survey still predominate in *Zone 4* and are closely bordered by steep ravines covered with dense willow, poplar and spruce. Grass and moss dominate the riparian vegetation along the banks which are undercut in a number of places.. Streambeds in some locations in this zone appear to be relatively stable, compared with general observations from 1980, as evidenced by the abundance of vegetation along the stream banks, water depth, and presence of large anchor rocks on the stream bottom.

In *Zone 5*, a steep eroded slope occurs along the eastern side of this area making accessibility difficult as mentioned in the 1980 survey. Topography is more gradual in the riparian zone along the west side which consists of a flat rocky bank leading up to a steep treed slope. Stands in the area include mixed poplar, birch and willow along the riparian zone in addition to grasses and shrubs. Stream flows in this area are slower owing to wider channels. Riffle areas predominate with a few pools, along with a number of undercut stream bank areas.

Observations mentioned in 1980 still apply to *Zone 6* of the creek, which consists of abundant pools, steep eroded banks and/or undercuts in some locations, and abundant riparian vegetation. Cobble and gravel predominate in the midstream creek-bed, with medium sand/silt along the creek edges. A beaver dam situated upstream, 100 m above the Fortymile town site bridge, may have gradually altered stream flow in these lower areas (Photograph 4.3) as well as affecting the upstream migration of fish past this area.

The reference location, *Mickey Creek* (Pat Roach, DIAND, pers. comm., 1998), assessed during the recent study only was situated approximately 1 km upstream from the south shore of Forty Mile River just below a road culvert undercutting the Forty Mile Creek access road. The stream is quite wide (~ 25 m) at this point and consists of a wide gravel/pebble shoal along its centre, and a coarse gravel/sand streambed along the shore edges. Riparian vegetation is quite dense in this area and consists of mixed willow, birch and grasses. The creek bank is undercut in a number of places, particularly along the east shore.

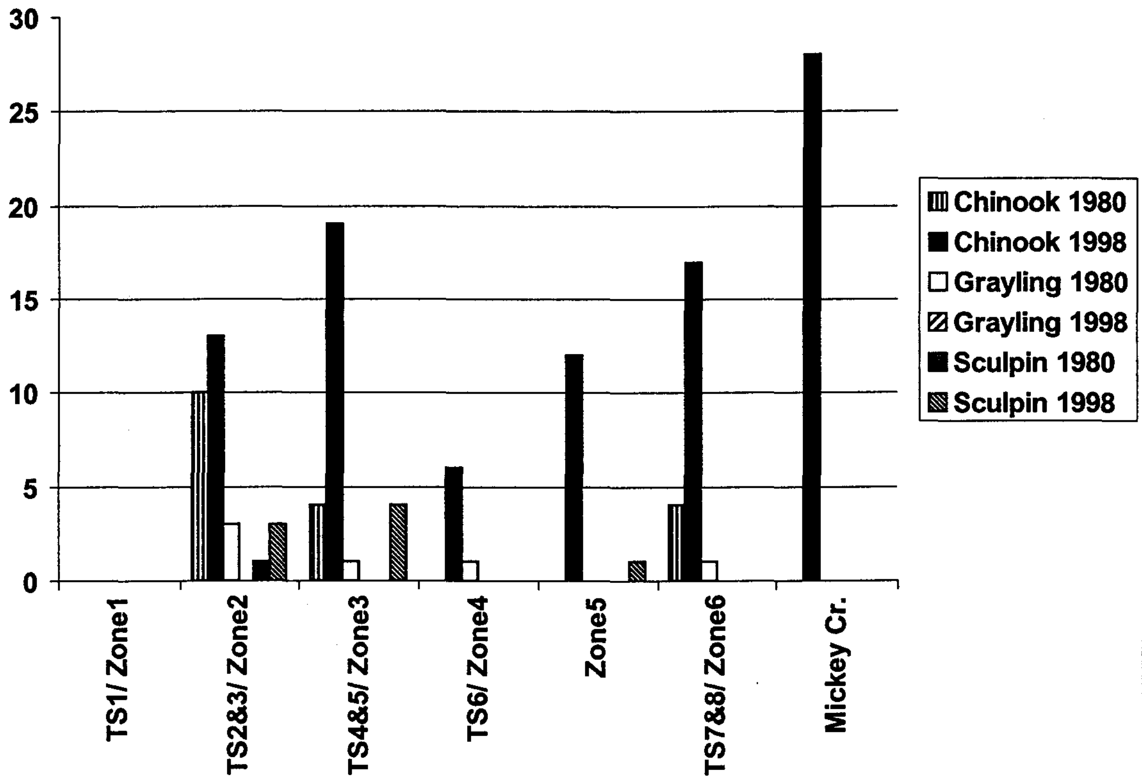
Overall, the most significant changes in fish habitat since 1980 appear to have occurred in the upper reaches of Clinton Creek near the minesite. Increased slumping and channel slope erosion, combined with a very limited amount of riparian vegetation establishment has occurred in Zone 1, continuing to make fry habitat and accessibility poor in this area. By contrast, noticeable improvements have occurred to fish habitat in Zone 2 with significant re-establishment of forest trees and riparian vegetation, consolidation of previously networked stream flows through the establishment of a beaver dam, and greater stream habitat stability. Habitat conditions in lower, downstream zones of Clinton Creek remain relatively stable and are similar in characteristic to the reference location in Mickey Creek.

4.2.1.2 Fishery Resources

Minnow Trap Census: Fry counts based on the census obtained from the minnow traps are provided, along with the census results from the 1980 study in Figure 4.4, below. Chinook salmon fry (*Oncorhynchus tshawytscha*) were obtained in 1998 traps set in virtually every study zone of Clinton Creek with the exception of Zone 1 near the outlet of Hudgeon Lake, where no fish were found. The absence of fry in Zone 1 correlates well with the poor fry habitat and accessibility observed as part of biophysical surveys at this location. All Chinook obtained in Clinton Creek were from the same young-of-the-year age class (0+) resulting from the 1997 spawn (Photograph 4.4). The largest number of Chinook fry were obtained in Zone 3 with a total of 19, compared with the lowest number of 6 from Zone 4 located further downstream from the mine site.

These numbers were still lower than the maximum number of Chinook fry (27) obtained at the reference location in Mickey Creek at this time of year (September). A number of factors might have accounted for the lower numbers of fry in Clinton Creek relative to the reference location, including drainage basin differences in water temperature, stream volume flows, and/or physical barriers.

Figure 4.4 Minnow Trap Results for Chinook Fry (EVS, 1980 and Current Study 1998)



The 1998 census numbers, nevertheless, were still higher than those obtained in 1980 where the maximum number (10) was found in Zone 2, and no Chinook fry were found in Zone 4. This is a particularly significant difference given that a much shorter census time was used in 1998 (one day) compared with the six day sampling program used in the 1980 study. It should also be noted that the Department of Fisheries and Oceans (DFO) reports that the Canadian chinook salmon escapement for 1997 in the Yukon River basin was among the highest on record, resulting in a correspondingly high number of 0+ fry (Al von Finster, HEB, DFO, pers. comm., 1999). The same DFO personnel suggest that the capture rate in the current study might have been considerably higher if conducted earlier in the year prior to seasonal changes and migration.

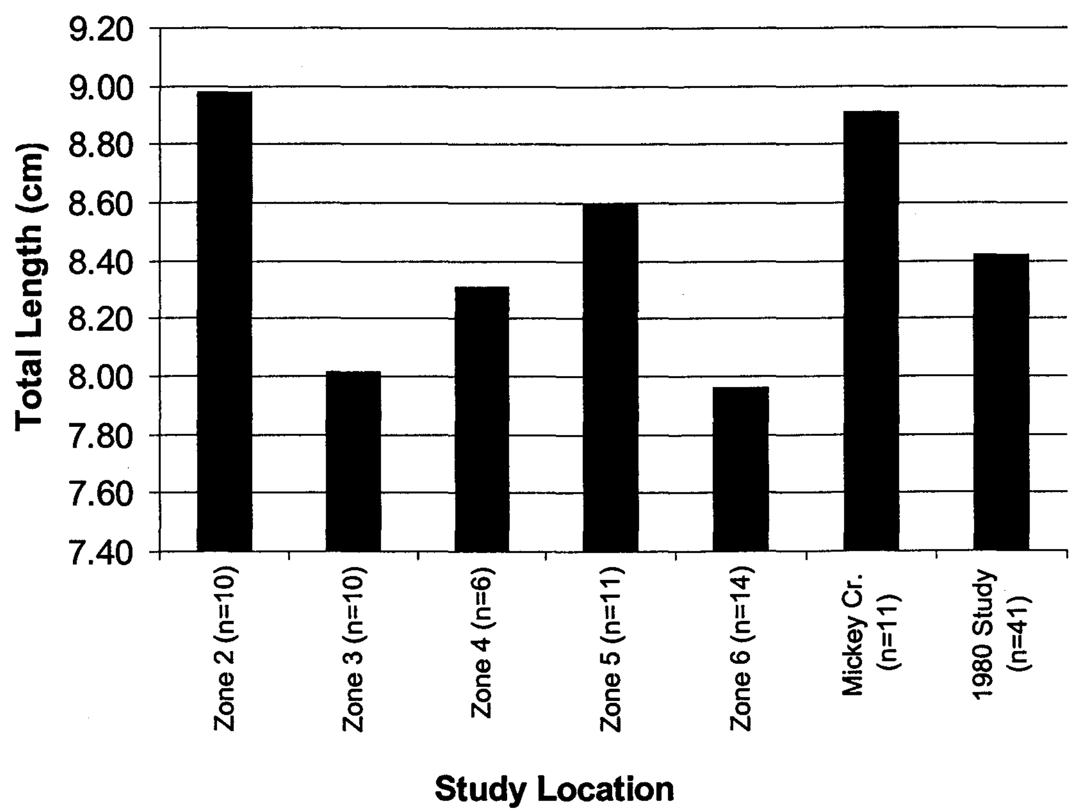
Sculpin (*Cottus cognatus*) were not as common in the traps as chinook, but maximum numbers were still higher and more common in 1998 compared with 1980, as demonstrated in Zones 2, 3 and 5 (Figure 4.4).

By stark contrast, no Arctic grayling fry (*Thymallus arcticus*), which comprised most of the 1980 minnow trap fry census, were found in any of the 1998 minnow traps set in Clinton Creek. This may have been due to a number of factors including the baiting and types of traps used. Subsequent sampling and further analysis, nevertheless would be required to confirm any trends.

Although the above results are based solely on one-time sampling events, they do suggest on a preliminary basis: i) an increase in the Chinook fry population of Clinton Creek; and ii) a significant shift in the composition of fry populations from freshwater Arctic Grayling to anadromous Chinook salmon since 1980. Additional minnow trap sampling at earlier times (prior to fall migration) in subsequent years would be required to properly verify this.

Fry Size Analysis: Measurements (total length) of harvested Chinook fry from minnow traps in 1998 are provided in Figure 4.5 below; the average for the 1980 study is also presented for comparison. The largest juveniles on average were found in Zone 2 (8.98 cm, n = 10), the section of the river closest to Hudgeon Lake where fry were observed to occur. This correlates well with the more abundant upstream food supply provided by Hudgeon Lake discussed below. This size is also comparable to fish obtained from the reference site in Mickey Creek (average 8.91 cm, n = 11). The average size of Chinook fry from the earlier study (8.42 cm, n= 41) was similar to the average size measured in the subset from 1998 study (8.35 cm, n=51) suggesting no significant difference in (young-of–the-year) fry size or vigour in the Clinton Creek watershed between the two studies.

Figure 4-5: Length of Chinook Fry from Clinton Creek (1998 & 1980)



Gillnetting: Poor fishing success was noted in the 1980 study in which only three adult (Arctic) grayling specimens were obtained after a 66 hour period in Hudgeon Lake at the head of Clinton Creek. These fish were obtained in the intermediate (6.4 cm) mesh size and it was concluded by EVS that the lake supported a small grayling population. No fish were captured following 48 hours of gill-netting at the same location in 1998. It should be noted, however that a 6.4 cm gill net was not used in the 1998 study which might have accounted for the lack of any fishing success. In addition, gillnetting was only conducted at one end of the lake. Although the head of the creek would be anticipated to be the section where older fish would be more likely to occur, other areas of the lake were not investigated. It is noted by DFO personnel that overwintering areas for grayling might be quite confined (Al von Finster, HEB, DFO, pers. comm., 1999) resulting in mis-leading conclusions over their presence based on a results from a single section of the lake during the fall period of the study. Nevertheless, if the lake supported a healthy and balanced age class population of Arctic Grayling, it would be anticipated that larger fish representing older year classes would have been captured in the larger mesh size.

The above preliminary results suggest, at the very least, that no significant improvements have occurred in the Arctic grayling population of Hudgeon Lake since 1980. The absence of fry in Clinton Creek, based on preliminary minnow trap studies also places some possible doubt as to the current existence of any viable resident grayling population in the Clinton Creek watershed. This is also supported by i) questionable anoxic water conditions as indicated by hydrogen sulphide detected in the hypolimnion of the lake (maximum depth 27 m), and ii) the lack of any visible evidence of adult fish in the lake waters or creek during the 1998 study.

Although it seems unlikely that a viable *resident* grayling population exists in the section of the Clinton Creek watershed studied, it is difficult to determine whether the creek is used for summer feeding or rearing from one or more *transient* stocks originating from Forty Mile River, based on the fall timing of studies to date.

During more recent investigations into the water quality of Hudgeon Lake conducted in July, 1999 (Indian and Northern Affairs, 1999), a small number of young fish less than 15 cm in size were observed rising by the outflow of the lake into Clinton Creek. Although the fish species could not be determined, similar observations of fish in the previous year suggested these to be a temporary group of summer residents (possibly Grayling) migrating upstream from Clinton Creek. Poor water quality conditions in the lake were described as likely precluding the survivorship of a year-round population (Indian and Northern Affairs, 1999).

These conclusions would have to be confirmed through additional minnow trap and electrofishing efforts in Clinton Creek at other times of the year, the set-up of a full mesh-size range of gill nets at other locations in Hudgeon Lake, and further investigations into the lake's hypolimnetic water quality (e.g., dissolved oxygen, pH, temperature, dissolved inorganic substances).

Electrofishing: The 1980 electroshock survey conducted along the different zones of Clinton Creek indicated that Chinook salmon juveniles appeared to be "evenly distributed throughout the watershed, whereas grayling were heavily concentrated in the mid and lower reaches of Section 1" (EVS, 1981). Based on these 1980 results and those from a two-way fish weir survey, the report concluded that these two fish in addition to Sculpin were the three species inhabiting the creek watershed. The earlier report also indicated that a more diverse fishery compared to the present survey was observed during a 1975 study conducted by EPS (1977), in which other species including long-nosed suckers, and lake and round whitefish were also recorded. This discrepancy in fish composition between the two studies was attributed to the expected fall migration of these other species to the Forty Mile River (EVS, 1981).

Electrofishing at the lower portion of the Clinton Creek in Zone 6 near the weir site at DS-2 in the current 1998 study yielded only two Chinook fry and one sculpin. The fry and sculpin were of similar size and age-class to conspecifics obtained in minnow traps in the upper regions of Clinton Creek. **The absence of any grayling or other adult fish in electrofishing samples from Zone 6 (compared with the 1980 study) and lack of visual evidence elsewhere upstream would again suggest that any *resident* adult populations of this species have declined in this watershed since the 1980 study.** As discussed above, this does not exclude the possibility of *transient* populations using the stream for summer feeding. **This conclusion, again, would have to be confirmed by additional electrofishing surveys (using stops nets) in summer to determine whether any early-season, adult transient fish species use the watershed, which may have been missed during the fall surveys.**

Invertebrate Drift and Plankton Samples: Large amounts of invertebrates (including *Daphnia* sp.) were collected in the surber sampler at the head of Clinton Creek, just below Hudgeon Lake in 1998. Significant, but smaller catches were also obtained in plankton samples from the water column within the lake. **These qualitative results correlate well with earlier findings and indicate that food productivity for fish in the Clinton Creek watershed, provided primarily from Hudgeon Lake, has remained favourable relative to the 1980 study.** No invertebrates, by comparison, were obtained in the surber sampler set up at the reference location in Mickey Creek. This discrepancy might have been related to the location of the trap and/or habitat conditions at the time of sampling such as a high water event from precipitation prior to sampling, or distance from higher productivity areas such as lakes or pools. **Additional sampling for invertebrate productivity is needed during the summer months, and in other areas of the watershed for the assessment of fish habitat.**

Photograph 4.1: Canyon area of Zone 1 in Clinton Creek below Hudgeon Lake showing steep scree slopes, exposed bedrock and swift currents downstream

Photograph 4.2: Zone 2 of Clinton Creek looking upstream towards beaver dam in background, side flooding channel on the right and Wolverine Creek confluence in lower right corner.

Photograph 4.3: Zone 6 looking downstream towards remnants of bridge and ford crossing to town site.

Photograph 4.4: Chinook salmon fry (0+ year class) captured in minnow trap from Zone 6.

4.2.2 Terrestrial Habitat

This region is naturally dominated by mature alpine spruce (*Picea* sp.) forests with a mix of other tree species including willow (*Salix* sp.) willow, birch (*Betula* sp.), ericaceous shrubs (berry plants), and balsam poplar (*Populus balsamifera*) in more open or disturbed areas. The forest areas are supported by a rich, moist, peat-organic layer (10 cm or more) over mixed shale and glacial till. Vegetative ground cover in these forests consists of moss and lichen species in addition to a variety of woodland grass and wildflower species (e.g., *Epilobium* sp. or fireweed) (Photograph 4.5).

Ecological footprints resulting from the mining activities are evident in highly disturbed areas of waste rock and mine tailings which have up-rooted and smothered existing forest in the area. This has left large expanses of virtually barren areas devoid of any vegetative ground cover. A stark example of this is provided in Photograph 4.6, taken between the north and south lobes along the east face of the tailings pile by Wolverine Creek, which shows a relic of the original forest in the area surrounded by the encroaching tailings pile. Vegetation and re-establishment (reclamation) in the areas of the waste rock and tailings areas based on the vegetative ground surveys and general observations are discussed in more detail below.

4.2.2.1 Vegetation Surveys

A summary of the results from ground vegetation surveys conducted at the waste rock (mine) and tailings (mill) sites are provided in Table 4-2; the survey data can be found in Appendix B.

Table 4-2: Summary of Results from Ground Vegetation Surveys

Location	n	Mean % Ground Cover (Range)	Mean No. of Species (Range)	Total No. of Species
Tailings (Mill Site)	10	19.6* (0-100)	1.2 (0-3)	5
Waste Rock (Mine)	12	9.7 (0-30)	1 (0-3)	5
Background	5	9.0 (0-45)	0.6 (0-3)	5

*Includes quadrat in isolated patch of dense scrub vegetation occurring between north and south peaks of tailings pile. Without this quadrat, mean = 10.7%.

Ground vegetation in the area of the *tailings (mill) site* was extremely scarce (mean of 19.6%) with 40% of the quadrats surveyed being completely bare. This was particularly true along the north, east and south slopes of the tailings pile above the surrounding forests which were void of any ground cover (Photograph 4.7). Most vegetation, although scarce, was found at the top of the tailings piles and the mill site just to the north.

A few anomalies were found on the tailings including a low-lying area of darker substrate between the north and south peaks of the tailings pile (CLMS-5) which contained a small dense patch of scrub vegetation; ground cover (including moss) at this location reached 100% (Photograph 4.8). Although trees were absent in the tailings site, a few spruce saplings (up to 40 cm high) were noted in isolated locations on the north tailings pile. The most frequently occurring ground cover plants in the vegetation surveys were grasses, particularly wild barley (*Hordeum jubatum*) which was selected as the indicator species in the plant sampling program for possible chemical analysis in the future. Plant diversity within the plots as measured by the number of species was, otherwise, very low.

Indirect effects of tailings pile smothering are also evident along the forest edges bordering the area in which particulates from wind and snow have coated the leaf surfaces of spruce (Photograph 4.9) resulting in a chronic smothering and eventual death of these trees. This, aside from substrate chemistry, is probably also a major factor impeding natural reclamation at this site.

Ground vegetation at the *waste rock (mine) site* was not unlike that of the tailings in which cover was again quite scarce (mean of 9.7%), with 50% of the survey quadrats being bare. Unlike the tailings pile, most of the direct ecological effects here have come more from the direct digging and up-rooting of the original forest, as opposed to smothering from materials. The substrate in the waste rock area is considerably more coarse grain than the finer particles at the tailings site from the milling process. The re-establishment of trees and vegetation in general, nevertheless, has been much greater at this site than at the tailings pile, particularly in less disturbed areas between roads (Photograph 4.10). Tree species present on the site included willow and balsam poplar present in small to moderate stands, and more slow-growing spruce seedlings. The most frequently occurring ground cover plants in the vegetation surveys, as for the tailing site, were grasses, particularly wild barley (*Hordeum jubatum*) which was selected as an indicator species. Plant diversity within the plots as measured by the number of species was also very low.

The ground vegetation survey results for the tailings and waste rock sites did not differ significantly from the background locations (Table 4-2, above). It should be noted, however, that the establishment of effective reference or background plots was difficult as the naturally-occurring vegetation type was mature spruce forest which is vastly different in soil composition (rich organic soil and peat vs. sand and gravel) and underlying ground cover (established woodland plants vs. early succession grasses such as wild barley). As a result, waste areas along the mine access road were primarily used to obtain background samples of wild barley for plants and glacial tills for soils, which were not necessarily reflective of the forest.

4.2.2.2 Wildlife

A wide variety of organisms were observed to use the site either directly or indirectly including raptors (hawks and owls) for foraging, waterfowl swimming on Hudgeon Lake, snowshoe hare and crows along Clinton Creek, beaver colonies in Clinton and Wolverine Creeks (Photograph 4.11), and moose (tracks) by the tailings site. A bear was also seen during the site reconnaissance survey.

In terms of potential wildlife receptors, the beaver colony occurring in Wolverine Creek adjacent to the mine tailings would be at the greatest risk given that these organisms and their associated structures (e.g., lodges and dams) may come in direct physical and (potentially) chemical contact with the tailings at this point (Photograph 4.12).

Moose and possibly other game animals also occur in the vicinity of the tailings and waste rock sites. The potential for direct contact with waste materials by the receptors, however, is less likely given that a very limited amount of palatable vegetation is available for foraging at these sites and the areas are probably used more as migration routes. The majority of tracks in the vicinity of the tailings site were also limited to the base, suggesting that most of the time is spent along the forest edge as opposed to on the tailings piles themselves.

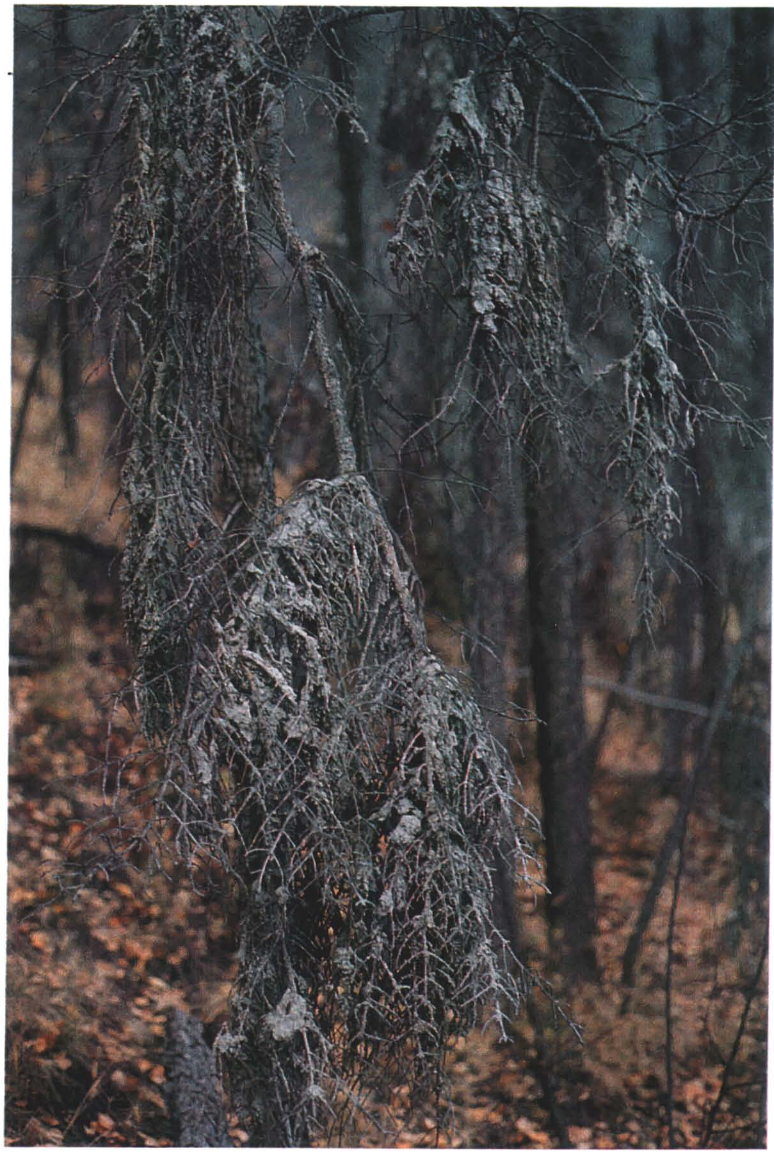
Most other wildlife, particularly avifauna, are not as likely to come in direct contact with the tailings, as a majority tended to forage in areas outside of the direct influence of the mine waste materials such as Hudgeon Lake and areas of Clinton Creek below the mine site. The indirect risks to waterfowl using Hudgeon Lake from the (hydrogen) sulfide-rich hypolimnion in Hudgeon Lake, however, may merit some additional analysis.

Photograph 4.5: Survey quadrat at a reference location, CLMS-13, showing naturally occurring groundcover in surrounding spruce forests.

Photograph 4.6: Relic forest patch along east slope of tailings pile by Wolverine Creek.

Photograph 4.7: Southeast slope of tailings pile from Wolverine Creek showing barren surfaces absent of any groundcover.

Photograph 4.8: Isolated patch of scrub vegetation at top of tailings pile between north and south peaks; the latter can be seen in the background.



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Photograph 4.9: Indirect smothering of tree leaf surfaces from wind and snow blown tailing materials along forest edge to the south of the site.

Photograph 4.10: Establishment of trees (primarily willow, birch and balsam poplar) between roadways on the Clinton Waste Rock Dump.

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Photograph 4.11: Active beaver lodge along shoreline in widening area of Wolverine Creek; the north lobe of the tailings pile can be seen in the background to the south.

Photograph 4.12: Beaver dam in contact with edge of tailings pile at the south outlet of Wolverine Creek near WC-2/3.

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4.3 Geochemical Stability of Waste Rock and Tailings Materials - Analysis of Potential for Metals Input

4.3.1 Assessment Criteria

In order to determine the potential for the input of metals into an ecosystem, it is necessary to ascertain the concentrations at which these elements could lead to a decrease in environmental quality. An initial approach to this exercise is to compare the metal concentrations to appropriate benchmarks. Preliminary guidance on acceptable levels of analytes in soil and water samples collected from the waste rock and tailings piles was obtained from the following:

- **CCME (Canadian Council of Ministers of the Environment) Canadian Environmental Quality Guidelines (EQGs)**

The EQGs provide a broad range of environmental assessment and management functions including the following, which are relevant to this investigation:

- a national benchmark to determine impairment of socially-relevant resource uses;
- scientific benchmarks or targets in the assessment and remediation of contaminated sites; and
- as the scientific basis for the development of site specific objectives

Thus comparison of contaminant concentrations in samples collected from the site with the EQGs provides a simple, screening-level evaluation of the likelihood of risk to humans, other animals, plants, and other living receptors that use the site or are part of the larger ecosystem. Contaminant concentrations that exceed the benchmarks do not necessarily result in harmful impacts; rather, environmental concentrations below the benchmarks are very unlikely to cause harm. Contaminant concentrations in excess of the relevant criterion or standard may or may not lead to elevated risk depending on a large suite of site specific conditions, including the organisms present. During preliminary site investigations, soil and water quality criteria are appropriately used as benchmarks only in order to determine the need for more detailed study.

The CCME EQGs are divided into four land use categories – agricultural, residential, commercial and industrial. The Clinton Creek watershed is currently used for recreational purposes and the residential/parkland criteria may be the most appropriate. The agricultural criteria were deemed inappropriate since they were developed for land use involving intensive and repeated sowing and harvesting of plants and intense livestock husbandry, and are based on scientific information such as the bioaccumulation of contaminants by livestock feeding exclusively on plants grown in contaminated soils.

A summary of the relevant existing Canadian Environmental Quality Guidelines is given in Table 4-3.

Table 4-3: Summary of Relevant Existing Canadian Environmental Quality Guidelines for Soil (CCME 1998)

Parameter	Agricultural Land Uses mg/kg	Residential/Parkland Land Uses (R/P) mg/kg	Industrial Land Uses mg/kg
Total Metals			
Antimony (Sb)	*20*see note*	*20*	*40*
Arsenic (As)	12	12	12
Barium (Ba)	750	500	2000
Beryllium (Be)	*4*	*4*	*8*
Cadmium (Cd)	1.4	10	22
Chromium (Cr)	64	64	87
Cobalt (Co)	*200*	*400*	*2000*
Copper (Cu)	63	63	91
Lead (Pb)	70	140	260
Mercury (Hg)	6.6	6.6	50
Molybdenum (Mo)	*5*	*10*	*40*
Nickel (Ni)	50	50	50
Selenium (Se)	*2*	*3*	*10*
Silver (Ag)	*20*	*20*	*40*
Tin (Sn)	*5*	*50*	*300*
Vanadium (V)	-	-	-
Zinc (Zn)	200	200	360

Note: Where no numerical values are provided in the CCME 1998 Soil Quality Guidelines for the Protection of Environmental and Human Health, the 1991 CCME Interim remediation criteria for soil are provided, in italics.

4.3.2 Background Conditions

The concentrations of metals and metalloids, which occur naturally in the earth's crust, depend on the prevailing geology, and can be highly variable. Soil samples collected from areas in the watershed, outside of the influence of the abandoned asbestos mine and with substrate similar to the waste rock, were analyzed to determine background conditions. The concentrations of metals and asbestos in these samples are given Table 4-4. The CCME EQGs for residential/parkland land use (R/P) is also provided for comparison.

Table 4-4: Concentrations, mean and standard deviations of metals (mg/kg) and asbestos (%) in background (reference) soil samples collected at Clinton Creek.

Sample ID	CCME R/P	CLMS-13	CLBK-1	CBLK-2	CBLK-3	Arith. Mean	Standard Deviation
Physical Tests							
pH		7.02	8.69	8.9	7.64	8.06	0.89
Total Metals							
Antimony (Sb)	*20*	<20	<200	<20	<100	-	-
Arsenic (As)	12	7	167	15	20	52	77
Barium (Ba)	500	270	3160	893	76	1100	1417
Beryllium (Be)	*4*	0.8	<4	0.8	<3	0.8	0
Cadmium (Cd)	10	0.4	<0.1	2.4	<0.1	1.4	1.4
Chromium (Cr)	64	36	3010	132	1420	1150	1392
Cobalt (Co)	*400*	19	134	12	70	59	56
Copper (Cu)	63	42	20	39	7	27	17
Lead (Pb)	140	<50	<400	<50	<300	-	-
Mercury (Hg)	6.6	0.057	0.078	0.162	0.051	0.087	0.051
Molybdenum (Mo)	*10*	<4	<30	6	<20	-	-
Nickel (Ni)	50	54	2560	183	1760	1139	1224
Selenium (Se)	*3*	1.1	0.2	9	<0.1	3	5
Silver (Ag)	*20*	<2	<20	<2	<10	-	-
Tin (Sn)	*50*	<10	<70	<10	<50	-	-
Vanadium (V)	-	43	51	40	13	37	17
Zinc (Zn)	200	122	37	103	16	70	51
Asbestos						-	-
Chrysotile		<1	3-5			-	-

*Shaded areas indicate parameters that exceed the CCME R/P EQG.

The average pH of the samples was 8.06 indicating alkaline conditions. Antimony, lead, molybdenum, silver and tin were generally below the detection limits. Detection limits for these five elements were high due to matrix interference caused by elevated chromium and nickel concentrations found in the samples. **The mean concentrations of chromium (1150 mg/kg) and nickel (1139 mg/kg) far exceeded the CCME guideline for residential parkland use; the levels also exceeded the CCME industrial guideline. High levels of nickel and chromium are typical of serpentine rich material (Ripley et. al., 1996). Thus the results obtained reflect the high degree of serpentine mineralization in the Clinton Creek water shed.** Arsenic (mean = 52 mg/kg) and barium (mean = 1100 mg/kg) also exceeded both the CCME R/P and industrial guideline. The high pH, nickel and chromium concentrations are similar to those of serpentine-derived soils that occur in Quebec (Ripley et. al., 1996).

4.3.3 Waste Rock

Elevated concentrations of arsenic, barium, chromium and nickel, which exceeded the CCME R/P guideline, were found in samples collected from the waste rock area (Table 4-5). The concentrations were, however, comparable to those detected in background samples and reflect the presence of serpentine in the waste rocks. Soil pH and asbestos results were also comparable to the background data.

Table 4-5: Concentration of metals (mg/kg) and asbestos (%) in samples collected from waste Rock at Clinton Creek.

Sample ID	CCME R/P	CLWR-3	CLWR-4	CLWR-5	CLWR-6	CLWR-7	CLWR-10	CLWR-11
Physical Tests								
pH		7.92	8.03	8.44	7.86	8.42	8.38	8.01
Total Metals								
Antimony (Sb)	*20*	<20	<20	<80	<100	<100	<80	<20
Arsenic (As)	12	13	14	28	13	17	15	18
Barium (Ba)	500	84	103	65	397	1060	10	296
Beryllium (Be)	*4*	0.5	0.7	<2	<3	<3	<2	0.8
Cadmium (Cd)	10	2.3	2.5	0.2	<0.1	0.5	<0.1	1.6
Chromium (Cr)	64	19	22	1110	1810	625	1180	486
Cobalt (Co)	*400*	15	15	55	105	46	76	49
Copper (Cu)	63	58	62	25	10	21	14	48
Lead (Pb)	140	<50	<50	<200	<300	<300	<200	<50
Mercury (Hg)	6.6	0.299	0.343	0.046	0.142	0.167	0.197	0.297
Molybdenum (Mo)	*10*	14	16	<20	<20	<20	<20	12
Nickel (Ni)	50	65	64	1230	852	867	1710	834
Selenium (Se)	3	8	8	0.3	0.1	1.2	<0.1	4.4
Silver (Ag)	*20*	<2	<2	<8	<10	<10	<8	<2
Tin (Sn)	*50*	<10	<10	<40	<50	<50	<40	<10
Vanadium (V)	-	30	36	23	66	47	<8	38
Zinc (Zn)	200	248	238	29	27	71	8	143
Asbestos								
Chrysotile		3-5			<1			7

*Shaded areas indicate parameters that exceed the CCME R/P EQG.

4.3.4 Tailings

Samples of tailings were collected from different areas of the North and South lobes and locations were selected to represent high points, drainage pathways, drainage catchments and vegetated areas. Two of the sampling locations are shown in Photograph 4-13 and 4-14.

Eight samples were analyzed for metals. Except for the concentration of arsenic in three samples, metal levels in the samples collected from tailings at the mill site (Table 4-6) were comparable to those obtained for the waste rock and background samples. Arsenic concentrations were 160, 265 and 321 mg/kg in samples CLMS-5, CLMS-9 and CLMS-10, respectively.

Asbestos concentrations were also high ranging between 15 and 40% and pH's were consistently alkaline.

Table 4-6: Concentrations of Metals (mg/kg) and Asbestos (%) in Samples Collected from Tailings at the Mill Site.

Sample ID	CCME R/P	CLMS-1	CLMS-2	CLMS-3	CLMS-5	CLMS-9	CLMS-10	CLMS-11	CLMS-12
Physical Tests									
pH		8.86	9.08	8.59	7.93	8.43	8.52	9.55	8.56
Total Metals									
Antimony (Sb)	*20*	<100	<100	<100	<40	<80	<60	<40	<100
Arsenic (As)	12	74	14	3.2	160	265	321	2.4	2.4
Barium (Ba)	500	981	207	279	502	228	588	5	346
Beryllium (Be)	*4*	<3	<3	<3	<1	<2	<2	<1	<3
Cadmium (Cd)	10	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	<0.1
Chromium (Cr)	64	1410	1380	1650	771	928	1430	1530	1470
Cobalt (Co)	*400*	103	81	87	60	76	99	65	111
Copper (Cu)	63	7	<5	<5	30	<4	3	<2	<5
Lead (Pb)	140	<300	<300	<300	<100	<200	<200	<100	<300
Mercury (Hg)	6.6	0.109	0.018	0.018	0.172	0.409	0.444	<0.005	0.034
Molybdenum (Mo)	*10*	<20	<20	<20	<8	<20	<20	<8	<20
Nickel (Ni)	50	2210	2030	2140	1150	1740	2200	1640	2300
Selenium (Se)	3	<0.1	<0.1	<0.1	3.5	<0.1	<0.1	<0.1	0.1
Silver (Ag)	*20*	<10	<10	<10	<4	<8	<6	<4	<10
Tin (Sn)	*50*	<50	<50	<50	<20	<40	<30	<20	<50
Vanadium (V)	-	26	21	11	34	<8	19	8	20
Zinc (Zn)	200	30	13	14	133	6	12	9	14
Asbestos (%)									
Chrysotile		35	40	15		40	30		

*Shaded areas indicate parameters that exceed the CCME R/P EQG.

One sample (CLMS-14) collected from the south side of concrete foundation on the southern edge of Mill site near three standpipes (Photograph 4-13) was analyzed for PCBs as Aroclors. The foundation was thought to originally house large electrical transformers. The sample was obtained from the base of the middle standpipe that contained an oily residue to ascertain if any PCB containing fluids had been spilled in the area. The concentration of PCBs in this sample was below detection (<0.5 mg/kg).

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Photograph 4-13: Concrete foundations and remnants of fence with on the southern edge of Mill site. Note tailings and crushed rocks in the vicinity

Photograph 4.14: Pool in a low-lying area at the Mill Site. Note crushed rocks and debris in the area.

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4.4 Evaluation of Downstream Waste Materials Redistribution using Chemical Tracers and Asbestos in Riverine Sediment Deposits

4.4.1 Assessment Criteria

The CCME Environmental Quality Guidelines for Water are divided into four usage categories - freshwater aquatic life, irrigation, livestock watering, and drinking water. The criteria for freshwater aquatic life are adopted unmodified from the Canadian Water Quality Guidelines (CWQG; CCREM, 1987). Guidelines for drinking water are taken unamended from the Guidelines for Canadian Drinking Water (GCDWQ; Health and Welfare Canada, 1989), and are the maximum acceptable concentrations for unfiltered samples at the point of consumption.

For surface waters collected in the Clinton Creek watershed, the CCME Environmental Quality Guidelines for freshwater aquatic life are relevant, as are drinking water standards where there is some reasonable expectation that the water might be used by humans for drinking. Numerical values for these two guidelines are given in Table 4-7, below. The CCME EQGs also contain numerical values for freshwater sediments and these are indicated in the table. No Canadian or Yukon standards or guidelines are available for asbestos in water or sediments.

There are currently no CCME EQG values for alkalinity and physical parameters such as temperature and conductivity. Conductivity is a measure of the ability of an aqueous solution to carry electric current between two electrodes. In solution the current flows by ion transport and therefore high conductivity indicates high ionic content. It is useful as a screening tool for indicating the presence of dissolved minerals. Alkalinity defines a water sample's capacity of to neutralize acids. It is a measure of all the compounds that are capable of elevating the pH of a solution and include dissolved calcium carbonate and the bicarbonates of calcium, sodium, and magnesium. Thus like conductivity above, it indicates the presence of dissolved minerals in solution. Hydroxides, phosphates, ammonium and other organic acids may also play a minor role in increasing the alkalinity of a water body. Increasing alkalinity decreases the toxicity of metals.

Table 4-7: Summary of Relevant Existing Canadian Environmental Quality Guidelines (CCME 1998)

Parameter	Water Freshwater µg/L	Drinking Water µg/L	Sediment Freshwater mg/kg
pH	6.5 – 9.0	6.5 – 8.5	-
Temperature	-	-	-
Conductivity	-	-	-
Dissolved Anions			
Alkalinity-Total $CaCO_3$	-	-	-
Bromide Br	-	-	-
Chloride Cl	-	≤250 000	-
Fluoride F	-	1500	-
Sulphate SO_4	-	≤500 000	-
Nutrients			
Nitrate Nitrogen N	Narrative	45 000	
Nitrite Nitrogen N			
Total Metals			
Aluminum T-Al	5 – 100	-	-
Antimony T-Sb	-	6	-
Arsenic T-As	5	25	5.9
Barium T-Ba	-	1000	-
Beryllium T-Be	-	-	-
Boron T-B	-	5000	-
Cadmium T-Cd	0.17	5	600
Calcium T-Ca	-	-	-
Chromium T-Cr	8.9 (as Cr III)	50	37.3
Cobalt T-Co	-	-	-
Copper T-Cu	2 – 4	10	35.7
Iron T-Fe	300	≤300 aesthetic	-
Lead T-Pb	1 – 7	10	35
Magnesium T-Mg	-	-	-
Manganese T-Mn	-	≤50 aesthetic	-
Mercury T-Hg	0.1	1.0	0.17
Molybdenum T-Mo	73	-	-
Nickel T-Ni	25 – 150	-	-
Selenium T-Se	1.0	10	-
Silver T-Ag	0.1	-	-
Thallium T-Tl	0.8	-	-
Uranium T-U	-	100	-
Zinc T-Zn	30	≤5000 aesthetic	123

4.4.2 Background/Reference Water Samples

The pH, conductivity, total alkalinity and the concentrations of dissolved anions, nutrients and total metals in three reference samples are given in Table 4-8. The samples were collected from a creek which feeds into the north arm of Hudgeon Lake (CLCR-5), Eagle Creek (CLCR-Z3B) and Fortymile River, upstream of the confluence of Clinton Creek.

The concentrations of most of the parameters were below detection. Of particular interest were the concentrations of arsenic, chromium, nickel which were found at elevated levels in substrate collected from waste rock and mine tailings. These elements were not detected in the water samples as a result of the high pH of soil samples, which keeps the metals out of solution. The water samples themselves were slightly alkaline. The low nutrient concentration and the high proportion of calcium and magnesium reflect the presence of serpentine rich materials in the Clinton Creek area.

The average concentrations of iron and aluminum exceeded the freshwater guidelines whiles the concentration of selenium in one of the samples (CLCR-Z3B) also exceeded the guidelines. The results were comparable to those found in samples collected in the Fisheries study of 1974 and 1975 (Fisheries and Environment Canada, 1997). For example, the concentrations of calcium in samples obtained from locations upstream of Hudgeon Lake and Wolverine Creek, upstream of tailings were between 28 and 32 mg/L. Magnesium concentrations from the same locations were between 2.7 – 37 mg/L.

Table 4-8: Physical Parameters and Concentrations (mg/L) of Anions, Nutrients and Metals in Background/Reference Samples

Sample Number	CLCR-5	CLCR-Z3B	CLCR-Z8	Mean
pH	7.43	7.23		
Temperature	5.0	2.6		
Conductivity (µS)	212	175		
Dissolved Anions				
Alkalinity-Total $CaCO_3$	101	-	-	
Bromide Br	<0.5	-	-	
Chloride Cl	<0.5	-	-	
Fluoride F	0.19	-	-	
Sulphate SO4	61	-	-	
Nutrients				
Nitrate Nitrogen N	<0.1	-	-	
Nitrite Nitrogen N	<0.1	-	-	
Total Metals				
Aluminum T-Al	0.066	0.98	0.28	0.44
Antimony T-Sb	<0.2	<0.2	<0.2	
Arsenic T-As	<0.2	<0.2	<0.2	
Barium T-Ba	0.03	0.08	0.04	0.05
Beryllium T-Be	<0.005	<0.005	<0.005	
Boron T-B	<0.1	<0.1	<0.1	
Cadmium T-Cd	<0.0002	<0.0002	<0.0002	
Calcium T-Ca	32.1	41.8	21.4	31.8
Chromium T-Cr	<0.01	<0.01	<0.01	
Cobalt T-Co	<0.01	<0.01	<0.01	
Copper T-Cu	<0.01	<0.01	<0.01	
Iron T-Fe	0.17	0.66	0.36	0.40
Lead T-Pb	<0.001	<0.001	<0.001	
Magnesium T-Mg	21.9	14.8	6.6	14.4
Manganese T-Mn	0.01	0.04	0.017	0.022
Mercury T-Hg	<0.00005	<0.00005	<0.00005	
Molybdenum T-Mo	<0.03	<0.03	<0.03	
Nickel T-Ni	<0.05	<0.05	<0.05	
Selenium T-Se	<0.001	0.0023	<0.001	
Silver T-Ag	<0.0001	<0.0001	<0.0001	
Thallium T-Tl	<0.0001	<0.0001	<0.0001	
Uranium T-U	0.00159	0.00078	0.00059	0.00099
Zinc T-Zn	<0.005	<0.005	<0.005	

Shaded areas indicate parameters that exceed the Freshwater guidelines.

4.4.3 Hudgeon Lake

4.4.3.1 Physical Parameters, Anions, and Nutrients in Water

Water quality parameters such as pH, conductivity, anions and nutrients were determined in determined in five water samples collected from Hudgeon (Table 4-9). The general water quality parameters (pH and conductivity), as well as the concentrations of bromide, chloride, fluoride, nitrite and nitrates were comparable to those obtained for the reference locations in all the samples except for CLCR-6A. Sample CLCR-6A was collected from a depth of about 10 m at the centre of Hudgeon Lake. A strong hydrogen sulfide odour (rotten egg) was noted during sampling. The concentration of sulphate (307 mg/L) supported this field observation. This suggested that the lower depths of the lake were anoxic at the time of sampling.

Table 4-9: Physical Parameters and Concentration (mg/L) of Anions and Nutrients in Water Samples Collected from Hudgeon Lake

Sample Number	CLCR-2	CLCR-4	CLCR-6	CLCR-6A	CLCR-7
Physical Parameters					
pH	7.66	7.36	7.05	-	7.44
Temperature	8.5	9.9	8.4	-	8.2
Conductivity	307	310	312	-	289
Dissolved Anions					
Alkalinity-Total $CaCO_3$	105	-	102	337	98
Bromide Br	<0.5	-	<0.5	<0.5	<0.5
Chloride Cl	<0.5	-	<0.5	2.2	<0.5
Fluoride F	0.13	-	0.14	0.26	0.17
Sulphate SO_4	110	-	111	307	106
Nutrients					
Nitrate Nitrogen N	0.2	-	0.2	<0.1	0.2
Nitrite Nitrogen N	<0.1	-	<0.1	<0.1	<0.1

More recent investigations of lake water quality were conducted in July, 1999 by Indian and Northern Affairs using a Hydrolab® water sampler. Although dissolved oxygen levels were at 90% saturation in the first metre of the water column, surface temperatures (up to 20°C) in this water layer were determined to be prohibitively high to support salmonid species. Temperature and dissolved oxygen levels were reported to decrease rapidly below four metres, with the latter reaching concentrations below 1 ppm. It was concluded that, although environmental conditions might support salmonids in the 2 to 3 m range of the water column, year-round conditions for fish would likely be precluded by ice cover and poor water quality (Indian and Northern Affairs, 1999).

4.4.3.2 Metals in Water

In order to ascertain if the high levels of chromium and nickel detected in waste rock were being mobilized into the water column, seven water samples collected from Hudgeon Lake were analyzed for total metals. The results obtained are presented in Table 4-10.

Calcium and magnesium were found at elevated concentrations, while chromium, nickel and most of the remaining metals were below detection. Aluminum, selenium and iron were detected at concentrations exceeding the freshwater guidelines in some of the samples. These parameters were also elevated in the background samples. Generally the results agreed well with the background water samples data. The data for water samples also indicated that the high levels of chromium and nickel detected in the waste rock were not mobilized into the water column. The high pH of the waste rock precludes metal dissolution.

Table 4-10: Concentration (mg/L) of Total Metals in Water Samples Collected from Hudgeon Lake

Sample Number	CLCR-1	CLCR-2	CLCR-4	CLCR-6	CLCR-6A	CLCR-7	CLCR-9
Aluminum T-Al	0.059	0.067	0.063	0.062	0.08	0.123	0.059
Antimony T-Sb	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic T-As	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Barium T-Ba	0.05	0.05	0.05	0.05	0.11	0.05	0.05
Beryllium T-Be	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Boron T-B	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium T-Cd	<0.0002	<0.0002	<0.0002	<0.0002	<0.0004	<0.0002	<0.0002
Calcium T-Ca	46.8	46.7	45.4	45	122	45.7	44.9
Chromium T-Cr	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt T-Co	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper T-Cu	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron T-Fe	0.23	0.25	0.24	0.24	0.94	0.26	0.21
Lead T-Pb	<0.001	<0.001	<0.001	<0.001	<0.002	<0.001	<0.001
Magnesium T-Mg	26	27.1	26.3	26.3	67.7	25.8	25.7
Manganese T-Mn	0.11	0.118	0.107	0.117	2.7	0.112	0.111
Mercury T-Hg	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum T-Mo	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel T-Ni	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium T-Se	0.0014	<0.001	0.0009	<0.001	<0.002	0.0011	0.0013
Silver T-Ag	<0.0001	<0.0001	<0.0001	<0.0001	<0.0002	<0.0001	<0.0001
Thallium T-Tl	<0.0001	<0.0001	<0.0001	<0.0001	<0.0002	<0.0001	<0.0001
Uranium T-U	0.00141	0.00151	0.0015	0.00148	0.00231	0.00145	0.00141
Zinc T-Zn	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Shaded areas indicate parameters that exceed the freshwater guidelines.

4.4.3.3 Comparison of Total and Dissolved Metal Concentrations in Water

Aliquots of water samples obtained from Hudgeon Lake, along with a sample collected from Clinton Creek were filtered on site using 0.45μm inline filters for dissolved metals analysis. Comparisons of the concentrations for total and dissolved metals in the four pairs of water samples are given in Table 4-11. The dissolved metal concentrations were comparable to total metal concentrations for all the individual analytes except for aluminum. This indicated that the metals were mostly present in the dissolved form.

Table 4-11: Comparison of Concentrations (mg/L) of Total and Dissolved Metals in Water Samples.

Sample Number	CLCR-1		CLCR-2		CLCR-9		CLCR-Z6	
	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved
Aluminum	0.059	0.103	0.067	0.05	0.059	0.092	0.22	0.048
Antimony	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Barium	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Beryllium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Boron	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Calcium	46.8	45.2	46.7	47.8	44.9	46.1	53.5	53.2
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	0.23	0.25	0.25	0.23	0.21	0.22	0.42	0.23
Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Magnesium	26	26.2	27.1	27.7	25.7	26.4	35.8	35.7
Manganese	0.11	0.11	0.118	0.13	0.111	0.111	0.149	0.13
Mercury	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
olybdenum	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	0.0014	0.0012	<0.001	<0.001	0.0013	0.0011	0.0011	0.001
Silver	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Thallium	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Uranium	0.00141	0.00147	0.00151	0.00156	0.00141	0.00147	0.00142	0.00142
Zinc	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

4.4.3.4 Asbestos in Water and Sediments

Chrysotile asbestos was detected in sediments and water collected from Hudgeon Lake (Table 4-12). Concentrations in sediments were generally low (less than 5%) and comparable to the levels found in samples collected from waste rock (Table 4-5).

The highest concentration of chrysotile asbestos in the water samples, (112 x10^6 fibres/litre) was detected in sample CLCR-2, which was collected from the outlet of Hudgeon Lake. Concentrations in other areas of the lake varied between <1.07 fibres/litre to 13.96 x10^6 fibre/litre. The concentrations are comparable to the value of 19.8 x 10^6 fibre/litre found a grab sample collected from the lake in August 1995 (Roach, 1998). Thus the potential for the release of asbestos fibres into Hudgeon Lake continues to exist.

Table 4-12: Concentration of Chrysotile Asbestos in Sediment and Water Samples Collected from Hudgeon Lake.

Sample Number	Asbestos in Sediments (%)	Asbestos in Water (10^6 Fibres /Litre	
		Total	95% Confidence Limit
CLCR-2	3-5	112.73	89.13 – 143.03
CLCR-3	3-5	-	
CLCR-4	1-2	-	
CLCR-6	-	10.73	5.15 – 19.74
CLCR-6A	-	13.96	7.43 – 23.87
CLCR-7	<1	5.36	1.74 – 12.51
CLCR-8	-	<1.07	0.02 – 5.98
CLCR-5 (Reference Site)	1-2	8.59	3.71 – 16.92

4.4.4 Porcupine Creek and Waste Rock

4.4.4.1 Physical Parameters, Anions, and Nutrients in Water

Only one water sample (CLWR-7) collected from this area was analyzed. The concentration of sulphate in this sample, taken 2 m below the outlet of Porcupine Creek from the Creek Pit was 900 mg/L. This was the highest concentration detected at Clinton Creek. The concentrations of the other parameters were comparable to the background level.

Table 4-13: Physical Parameters and Concentration of Anions (mg/L) in Water Samples Collected from Porcupine Creek and Clinton Dump.

Sample Number	CLWR-7
pH	7.9
Dissolved Anions	
Alkalinity-Total CaCO3	223
Bromide Br	<0.5
Chloride Cl	0.7
Fluoride F	0.3
Sulphate SO4	900
Nutrients	
Nitrate Nitrogen N	0.5
Nitrite Nitrogen N	<0.1

4.4.4.2 Metals in Water

Metal concentrations in the water sample (CLWR-7) collected 2 m below the outlet of Porcupine Creek from the Creek Pit followed a similar pattern to that obtained for Hudgeon Lake (i.e., high concentration of calcium and magnesium with most of the remaining metals occurring at concentrations below the limits of detection). Similar results were also obtained for CLWR-13, which was collected from a natural spring on the side of embankment along Clinton Creek, approximately 40 m from the outlet (Table 4-14). The spring originated from the waste rock in the Clinton Dump and substrate in the receiving area was stained brown and covered with green algae.

Table 4-14: Concentration Total Metals (mg/L) in Water Samples Collected from Porcupine Creek and Clinton Dump.

Sample Number	CLWR-7	CLWR-13
Aluminum T-Al	0.006	0.01
Antimony T-Sb	<0.2	<0.2
Arsenic T-As	<0.2	<0.2
Barium T-Ba	0.02	0.06
Beryllium T-Be	<0.005	<0.005
Boron T-B	<0.1	<0.1
Cadmium T-Cd	<0.001	<0.001
Calcium T-Ca	270	141
Chromium T-Cr	<0.01	<0.01
Cobalt T-Co	<0.01	<0.01
Copper T-Cu	<0.01	<0.01
Iron T-Fe	<0.03	1.21
Lead T-Pb	<0.005	<0.005
Magnesium T-Mg	123	130
Manganese T-Mn	<0.005	1.18
Mercury T-Hg	<0.00005	<0.00005
Molybdenum T-Mo	<0.03	<0.03
Nickel T-Ni	<0.05	<0.05
Selenium T-Se	0.0081	<0.005
Silver T-Ag	<0.0005	<0.0005
Thallium T-Tl	<0.0005	<0.0005
Uranium T-U	0.00467	0.0004
Zinc T-Zn	<0.005	<0.005

Shaded areas indicate parameters that exceed the CCME freshwater guidelines

4.4.4.3 Asbestos in Water and sediments

Asbestos fibres were visible in the sediment at CLWR-7 and also in sediment and water sample obtained from the Porcupine Pit. These samples were consequently not analyzed for asbestos.

4.4.5 Wolverine Creek

4.4.5.1 Metals in Sediments

Since elevated levels of arsenic along with chromium and nickel were detected in the samples collected from the tailings (Section 4.3.4), one sediment sample (CLWC-1) and a pair of field duplicate samples (CLWC-2 and CLWC-3) were analyzed for pH and metals (Table 4-15). Sample CLWC-1 was obtained approximately 40 m northeast and upstream of edge of north lobe tailings pile while CLWC-2 and CLWC-3 were from the outlet of the pond directly below the south lobe tailings pile. Arsenic concentrations in the sediments (maximum of 11 mg/kg) were considerably lower than that found in the tailings (maximum of 321 mg/kg). Nickel and chromium in sediments directly below the tailings pile were however, comparable to the levels found in the tailings.

Table 4-15: Concentration of Metals (mg/kg) and pH of Sediment Samples Collected from Wolverine Creek.

Sample ID	CLWC-1	CLWC-2	CLWC-3
Physical Tests			
Moisture %	45.5	29.2	27.2
pH	6.46	8.53	8.37
Total Metals			
Antimony (Sb)	<20	<100	<100
Arsenic (As)	11	11	9
Barium (Ba)	223	41	49
Beryllium (Be)	<0.5	<3	<3
Cadmium (Cd)	0.6	<0.1	<0.1
Chromium (Cr)	62	1580	1670
Cobalt (Co)	11	88	89
Copper (Cu)	26	<5	5
Lead (Pb)	<50	<300	<300
Mercury (Hg)	0.08	0.011	0.016
Molybdenum (Mo)	5	<20	<20
Nickel (Ni)	70	1920	1860
Selenium (Se)	1.6	0.1	0.2
Silver (Ag)	<2	<10	<10
Tin (Sn)	<10	<50	<50
Vanadium (V)	30	14	21
Zinc (Zn)	97	19	25

4.4.5.2 Physical Parameters, Anions, Nutrients and Metals in Water

The concentrations of anions and other parameters in samples collected from the two locations discussed in the previous section, along with sample CLMS-1 are given in Table 4-16, below. Sample CLMS-1 was obtained from a small pool in a low-lying area at the Mill Site, approximately 250 m southwest of water tower in direct line with the cable towers (Photograph 4-14). Crushed green rocks and debris were nearby. The pH and concentrations of anions and nutrients were comparable to the background levels except for a higher pH and conductivity at CLMS-1. The pH at CLMS-1 was more alkaline (pH = 9.12) and may be attributed to the crushed green rocks (serpentinite) nearby

Table 4-16: Physical Parameters and Concentration of Anions (mg/L) in Water Samples Collected from Wolverine Creek.

Sample Number	CLWC-1	CLWC-2	CLWC-3	CLMS-1
pH	7.3	7.23	7.23	9.12
Temperature	5.0	5.0	5.0	5.3
Conductivity	-	-	-	780
Dissolved Anions				
Alkalinity-Total $CaCO_3$	87	88	86	-
Bromide Br	<0.5	<0.5	<0.5	-
Chloride Cl	0.6	0.6	0.6	-
Fluoride F	0.14	0.14	0.14	-
Sulphate SO_4	124	128	127	-
Nutrients				
Nitrate Nitrogen N	<0.1	<0.1	<0.1	-
Nitrite Nitrogen N	<0.1	<0.1	<0.1	-

4.4.5.3 Metals in Water

Metal concentrations generally followed the trend expected for serpentine rich materials - high concentrations of calcium and magnesium, and all other parameters occurring at concentration that were either close to or less than the detection limits (Table 4-17).

Table 4-17: Concentration of Total Metals (mg/L) in Water Samples Collected from Wolverine Creek.

Sample Number	CLWC-1	CLWC-2	CLWC-3	CLMS-1
Aluminum T-Al	0.246	0.193	-	0.006
Antimony T-Sb	<0.2	<0.2	-	<0.2
Arsenic T-As	<0.2	<0.2	-	<0.2
Barium T-Ba	0.05	0.05	-	0.04
Beryllium T-Be	<0.005	<0.005	-	<0.005
Boron T-B	<0.1	<0.1	-	0.6
Cadmium T-Cd	<0.0002	<0.0002	-	<0.0004
Calcium T-Ca	45.2	41.7	-	6.69
Chromium T-Cr	<0.01	<0.01	-	<0.01
Cobalt T-Co	<0.01	<0.01	-	<0.01
Copper T-Cu	<0.01	<0.01	-	<0.01
Iron T-Fe	0.39	0.34	-	<0.03
Lead T-Pb	<0.001	<0.001	-	<0.002
Magnesium T-Mg	29	28.3	-	150
Manganese T-Mn	0.091	0.07	-	<0.005
Mercury T-Hg	<0.00005	<0.00005	-	<0.00005
Molybdenum T-Mo	<0.03	<0.03	-	<0.03
Nickel T-Ni	<0.05	<0.05	-	<0.05
Selenium T-Se	<0.001	<0.001	-	0.0024
Silver T-Ag	<0.0001	<0.0001	-	<0.0002
Thallium T-Tl	<0.0001	<0.0001	-	<0.0002
Uranium T-U	0.00184	0.00176	-	<0.00002
Zinc T-Zn	<0.005	<0.005	-	<0.005

Shaded areas indicate parameters that exceed the CCME freshwater guidelines

4.4.5.4 Asbestos in Water and Sediments

The concentration of asbestos fibres in sample CLWC-1 obtained upstream of the tailings pile was less than 1% while detectable levels were found in samples CLWC-2 and CLWC-3 collected from the pond directly below the south lobe tailings pile (Table 4-18). Asbestos fibres were also detected in the water samples (CLWC-2 and CLWC-3) collected from the pond. The concentrations were comparable to that found in the water samples (16.7 x 10^6 fibres/litre) collected from the pond in July 1996 (Roach, 1998).

Table 4-18: Concentration of Chrysotile Asbestos in Sediment and Water Samples Collected from Wolverine Creek.

Sample Number	Asbestos in Sediments (%)	Asbestos in Water (10^6 Fibres /Litre	
		Total	95% Confidence Limit
CLWC-1	<1	-	-
CLWC-2	10	22.62	14.8 – 35.76
CLWC-3	3-5	9.66	4.43 – 18.34

4.4.6 Clinton Creek

4.4.6.1 Physical Parameters, Anions and Nutrients in Water

Given the low concentrations of anions and nutrients detected in waters which flow into Clinton Creek (i.e., Hudgeon Lake, Wolverine Creek and Porcupine Creek) the concentrations of these parameters were deemed to be of minor concern. Thus only one of the five water samples collected was analyzed for anions and nutrients. The results obtained (Table 4-19) indicated that these parameters were of minor concern.

Table 4-19: Physical Parameters and Concentration of Anions (mg/L) in Water Samples Collected from Clinton Creek.

Sample Number	CLCR-Z2	CLCR-Z3	CLCR-Z4	CLCR-Z5	CLCR-Z6
pH	7.53	7.44	7.39	7.27	7.46
Temperature	7.7	4.3	6.9	6.9	6.3
Conductivity	300	244	322	342	133
Dissolved Anions					
Alkalinity-Total CaCO3	-	-	-	-	120
Bromide Br	-	-	-	-	<0.5
Chloride Cl	-	-	-	-	0.7
Fluoride F	-	-	-	-	0.18
Sulphate SO4	-	-	-	-	148
Nutrients					
Nitrate Nitrogen N	-	-	-	-	0.2
Nitrite Nitrogen N	-	-	-	-	<0.1

4.4.6.2 Metals in Water

Only two of the five water samples collected were for metals since concentrations detected in Hudgeon Lake and Wolverine Creek were low. The results obtained (Table 4-20) indicated that these parameters were of minor concern.

Table 4-20: Concentration of Total Metals (mg/L) in Water Samples Collected from Clinton Creek.

Sample Number	CLCR-Z2	CLCR-Z6
Aluminum T-Al	0.061	0.22
Antimony T-Sb	<0.2	<0.2
Arsenic T-As	<0.2	<0.2
Barium T-Ba	0.05	0.05
Beryllium T-Be	<0.005	<0.005
Boron T-B	<0.1	<0.1
Cadmium T-Cd	<0.0002	<0.0002
Calcium T-Ca	48.3	53.5
Chromium T-Cr	<0.01	<0.01
Cobalt T-Co	<0.01	<0.01
Copper T-Cu	<0.01	<0.01
Iron T-Fe	0.27	0.42
Lead T-Pb	<0.001	<0.001
Magnesium T-Mg	27.7	35.8
Manganese T-Mn	0.108	0.149
Mercury T-Hg	<0.00005	<0.00005
Molybdenum T-Mo	<0.03	<0.03
Nickel T-Ni	<0.05	<0.05
Selenium T-Se	0.0012	0.0011
Silver T-Ag	<0.0001	<0.0001
Thallium T-Tl	<0.0001	<0.0001
Uranium T-U	0.00149	0.00142
Zinc T-Zn	<0.005	<0.005

4.4.6.3 Asbestos in Water and Sediments

The highest concentration of asbestos (3-5%) was detected in the sediment sample collected at Zone-2, the confluence of Wolverine Creek (Table 4-21). Concentrations in sediment samples collected downstream of this were either close to or less than the detection limit of <1%.

An unusual result was obtained for the analyses of asbestos in water: The highest level was detected in the sample taken from Zone 6, at the town site ford crossing. The concentration obtained (152 x10^6 fibres/litre) was the highest for all the water samples collected during the investigation and was also higher than the concentration of 1.20 x 10^6 fibre/litre detected in a sample taken from the same location in July 1996 (Roach, 1998).

Table 4-21: Concentration of Chrysotile Asbestos in Sediment and Water Samples Collected from Clinton Creek Downstream of Hudgeon lake.

Sample Number	Asbestos in Sediments (%)	Asbestos in Water (10^6 Fibres /Litre	
		Total	95% Confidence Limit
CLCR-Z2	3-5		
CLCR-Z3	<1	4.29	1.17 – 10.99
CLCR-Z3B	<1		
CLCR-Z4	1-2		
CLCR-Z5	<1		
CLCR-Z6	<1	152.45	119.9 – 191.52
CLCR-Z7	<1		
CLCR-Z8	<1	1.07	0.02 – 5.98

5. Preliminary Environmental Risk Assessment

5.1 General Considerations and Preliminary Interpretations of Risk

The preceding information, including that collated from existing documentation as well as new site data, is needed to assess the ongoing risks of the abandoned asbestos mine site to aquatic and terrestrial resident organisms, and to human beings. The possibilities of unacceptable risks owing to the abandoned mine site on Clinton Creek and tributaries can be assessed along a spectrum of possible scenarios for the future behaviour of waste rock and tailings deposits. The difficulties with stabilization of the waste rock and tailings deposits have caused and will continue to lead to chronic slumping and redistribution, especially in association with season cycles of snow fall followed by spring runoff and high hydrological flows in the watershed. **The past impacts and possible future risks owing to the long term, "chronic" redistribution of geological waste materials from the site are likely to be different in type and magnitude from the risk associated with varying degrees of "catastrophic" deposit and impoundment failures.** At an early stage of assessing ecological and human health risks, therefore, it would be appropriate to define the information needs for the two separate scenarios.

5.1.1 Risks Due to Chronic Mobilization of Minesite Wastes in the Watershed

The chronic release of particulates, including asbestos fibres, into the Clinton River ecosystem has occurred since the early 1970s. The fisheries habitat assessment originally conducted by Fisheries and Environment Canada (1977) and repeated during this study show that viable salmonid and, possibly, other fish populations occur downstream from the abandoned asbestos mine site at all reaches examined except within the immediate vicinity of the Hudgeon Lake outflow and waste rock impoundment. The recent study also suggested that the reaches of Clinton Creek and some of the tributaries downstream from the abandoned mine site are suitable habitat for juvenile Chinook.

This leaves at least three outstanding questions:

- Did the Chinook juveniles observed originate from lower reaches of the river, or is the watershed in the immediate vicinity of the abandoned mine suitable habitat for adult spawning?
- Do present 'chronic' releases of materials into Clinton Creek and tributaries affect the post-larval survival and overall productivity of Chinook or other fish stocks upstream from and in Fortymile River?
- Would a loss of spawning and/or juvenile Chinook habitat owing to massive waste deposit erosion and deposition represent an appreciable loss of the overall Chinook or other fish productivity in Fortymile River and the Yukon River?

The first and third of these questions might be addressed in part through additional observations of river habitat and salmonid use during the period of year corresponding to Chinook spawning in the region (see recommendations in Section 6).

Other concerns about the risks of chronic waste material inputs to stream invertebrate productivity, algae, or receptors in the riparian zone have been addressed in part by the habitat observations included in Section 4. **Except in the area immediately below Hudgeon Lake (Zone 1), the impacts to aquatic or riparian organisms appear to have diminished relative to previous studies and observations in the 1970s and 80s. In addition, future risks are not expected to increase based on a continued chronic, small-scale mobilization of geological materials from unstable waste rock and tailings deposits.**

The geochemical stability of the asbestos waste rock and tailings areas was examined in detail for the first time as part of this study. The metal/metalloid results for soil and sediment samples confirms the naturally elevated concentrations of arsenic, barium, calcium, chromium, magnesium, nickel, and selenium in particular. **These geologically elevated concentrations, however, were not obviously accompanied by elevated total or dissolved concentrations in lake or river water.**

In most cases, the metals in water or freshwater sediments were analyzed using sufficiently low analytical detection limits to assess the toxicological significance. This preliminary risk assessment employed the most up-to-date CCME accepted water quality guidelines for the protection of freshwater aquatic life or for use as drinking water by humans, as well as the CCME freshwater sediment quality guidelines.

For all samples collected, the concentrations of total metals/metalloids in sediments or freshwater were below concentrations that might lead to risks for the following substances:

- Barium
- Boron
- Chromium
- Lead
- Mercury
- Molybdenum
- Nickel
- Silver
- Thallium
- Uranium
- Zinc

For a small number of analytes, however, the analytical detection limit was too high relative to the respective CCME guidelines (elevated detection limits were due to interferences from high levels of cations such as calcium and magnesium in the water samples).

These included –

- Antimony (study detection limit of <0.2 mg/L; CCME drinking water guideline = 0.006 mg/L)

- Arsenic (study detection limit of <0.2 mg/L; CCME freshwater aquatic life guideline = 0.005 mg/L)
- Cadmium (study detection limit of <0.0002 mg/L; CCME freshwater aquatic life guideline = 0.000017 mg/L)
- Copper (study detection limit of <0.01 mg/L; CCME freshwater aquatic life guideline = 0.002 to 0.004 mg/L)

Cadmium and copper are not expected to be contaminants of concern based on the low concentrations found in "soil" samples collected from waste rock and tailing deposits. Arsenic and antimony, however, were found to occur in highly elevated concentrations in background geological materials in the region, as well as in waste rock and tailings samples. As for several of the metals/metalloids, arsenic and antimony may exhibit extremely limited solubility at the site, and the anthropogenically influenced portions of the watershed may experience similar water borne concentrations of these two metalloids to freshwater outside of the influence of the asbestos mine and mill site. The situation for arsenic and antimony, however, will require further scrutiny to confidently assess this hypothesis, using analytical methods capable of achieving analytical detection limits of around 0.001mg/L.

A few of the metals occurred in the water column based on freshwater samples collected at naturally elevated concentrations which exceed either CCME guidelines for freshwater aquatic life or drinking water aesthetic guidelines. These included –

- Aluminum (exceeded the freshwater aquatic life guideline of 0.005 to 0.100 mg/L in several samples)
- Iron (exceeded the freshwater aquatic life guideline of 0.300 mg/L in several samples)
- Manganese (exceeded the aesthetic standards for drinking water supplies, of 0.050 mg/L in most samples)
- Selenium (approached or exceeded the freshwater aquatic life guideline of 0.001 mg/L in the majority of samples analyzed)

Manganese can be eliminated as a metal of concern unless humans use the surface waters for drinking water supplies. In addition, the CCME guideline is an aesthetic guideline only. Given the natural geological conditions in the area, it is unlikely that aluminum, iron and selenium in freshwater have resulted in elevated risks to aquatic biota or terrestrial receptors in the vicinity of the rivers and creeks. Resident biota are expected to be adapted to the range of environmental exposure concentrations for these three metals/metalloids. These are not likely to be contaminants of concern, either based on chronic mobilization or in association with massive downstream materials transport.

Even under strongly reducing conditions, as observed in one water sample collected from the deeper section of the centre of Hudgeon Lake, elevated levels of the metals/metalloids expected to have the greatest toxicological significance were not observed. The results fit well with an expected reductive release under sulfide-rich, anoxic conditions, of calcium, iron, magnesium, and manganese; however, there was no evidence that dissolved arsenic, antimony, mercury, selenium or any of the other divalent metal ions were elevated relative to water samples from well oxygenated areas and depths of the lake. As mentioned above, the analytical detection limits for arsenic and antimony do not allow us to eliminate the possibility of risks from these metalloids, and additional sampling and analysis is merited.

The fact that Hudgeon Lake is seasonally dimictic should be considered in evaluating future risks for downstream receptors. The degree of anoxia in late summer/early fall or under ice, for example, has not been assessed. Nor has the possible effects of overturn events and downstream movement of sulfide-rich water masses. This is probably not of major concern, but the possibility has not been investigated formally or informally. The lack of capture of grayling or other fish species using gill nets deployed while in the field might attest to a seasonal anoxia, which may have affected overwintering survival.

Overall, chronic risks from the abandoned minesite owing to geochemical mobilization of metals/metalloids or other substances to the water appear to be unlikely. Anoxic bottom waters in Hudgeon Lake, however, may represent a worst-case for reduced geochemical stability and as a source of risk to ecological receptors in and downstream from the artificially-impounded lake. Limited additional study of lake stratification and metals/metalloids mobilization is advocated by us.

5.1.2 Massive Failure Scenarios

The vast majority of concerns, and hypotheses regarding risks, are based on a catastrophic-type waste rock, tailings and impounded water release to the ecosystem. The plausible risks, therefore, are directly related to the probability of massive slope and impoundment failures of varying degrees. We note from our review in Section 2 that there has been a divergence of opinions about the expected risk of a large-scale geophysical failure. This should be addressed, as it directly affects the credibility of virtually all other aspects of the assessment of risk. Some of the knowledge requirements for geophysical stability and predicted materials fate (based in part on the site hydrology) are being addressed separately (T. Wingrove, UMA Engineering; in progress).

5.2 A Suggested Conceptual Model for Ecological and Human Health Risks

The formalized assessment of possible risks to humans and/or biota within the Clinton Creek/Fortymile River valley near and downstream from the abandoned mine site requires an understanding of (i) the stressors of concern to various stakeholders and as identified through prior studies, and (ii) the important components of the ecosystem that are potentially at risk. It is also important during the early (problem formulation) stages of conducting a risk assessment to achieve agreement among the stakeholders about the aspects of perturbation or situation, as well as biotic components of the ecosystem, which are of minor importance only in terms of anticipated risks. It is generally accepted that ecological risk assessments should focus on the few species, communities, and exposure scenarios that are likely to influence risk management decisions, rather than spending time and resources on a large number of receptors and pathways (Suter, 1999).

The stressors and important ecosystem components deemed to be most relevant for assessing the future risks associated with the abandoned mine are provided in Tables 5-1 and 5-2. The rationale for inclusion of each of these is provided below in Section 5.3.

For each ecosystem component at risk, including human individuals, it will be important for decision makers to decide what level of demonstrated risk or ecological effect would be required in order to prompt various risk management and/or remedial strategies. In the case of human health risks possibly associated with catastrophic geophysical failures of tailings or waste materials, avoidance of risks through modification of human access might represent the most pragmatic, cost-effective approach. In the case of Chinook salmon or other fisheries populations, the final decisions regarding mitigative strategies will undoubtedly require a balancing of the costs of various risk management strategies relative to the direct and indirect costs of additional losses of important ecosystem components.

Risk-based management strategies arising from ecological and human health risk assessments are generally influenced by technical/scientific issues, as well as non-technical socio-cultural and sociopolitical concerns. Some of these elements in the context of the abandoned Cassiar Asbestos minesite undoubtedly include the fact that the Yukon River is a transboundary river, and Chinook salmon are anadromous species.

Table 5-1: Clinton Creek Abandoned Minesite – Important Stressors in the Context of Future Possible human Health and Ecological Risks.

Stressor	**Chronic Concern**	**Catastrophic Event Concern**
Asbestos in air (human health)	✓	
Asbestos in water	✓	✓
Other suspended sediments in water (and smothering of benthic habitat in Clinton Creek, Fortymile River, and other areas in the watershed)	✓	✓
Arsenic, antimony, selenium dissolution under anoxic bottom conditions in Hudgeon Lake	✓	
Catastrophic flooding, including massive erosion and stream bank failure		✓
Exacerbative role of extreme meteorological and hydrological conditions		✓

Table 5-2: Clinton Creek Abandoned Minesite – Important Ecosystem Components and Receptors Potentially at Risk.

Stressor	**Chronic Concern**	**Catastrophic Event Concern**
Human Risks Due to Flooding		✓
Terrestrial Mammals, Including Humans and Asbestos Inhalation Risks	✓	
Anadromous Fish Populations - Chinook Salmon	✓	✓
Non-anadromous Fish Populations and Communities	✓	✓
Birds and Mammals in the Riparian Zone and Riverine Environment		✓
Other Riverine Receptors		✓

A graphical summary of a suggested conceptual model for the Clinton Creek ecological and human health risk assessment is provided as Figures 5.1 and 5.2. The spatial scale for the study approach would depend heavily on an initial evaluation of the probability of and magnitude of a massive geophysical failure event, such as a major breach in the Hudgeon Lake waste rock impoundment. If such an event is accurately estimated to be highly improbable, then further study of watershed hydrology and downstream habitat might be limited. Alternatively, if such an event is deemed to have a reasonable possibility of future occurrence, then the broader risks merit more extensive investigation.

Section 6 provides additional investigations for follow-up actions, which includes both further study requirements as well as some preliminary ideas for the reduction of future risks, based on the re-vegetation and stabilization of mine waste deposits.

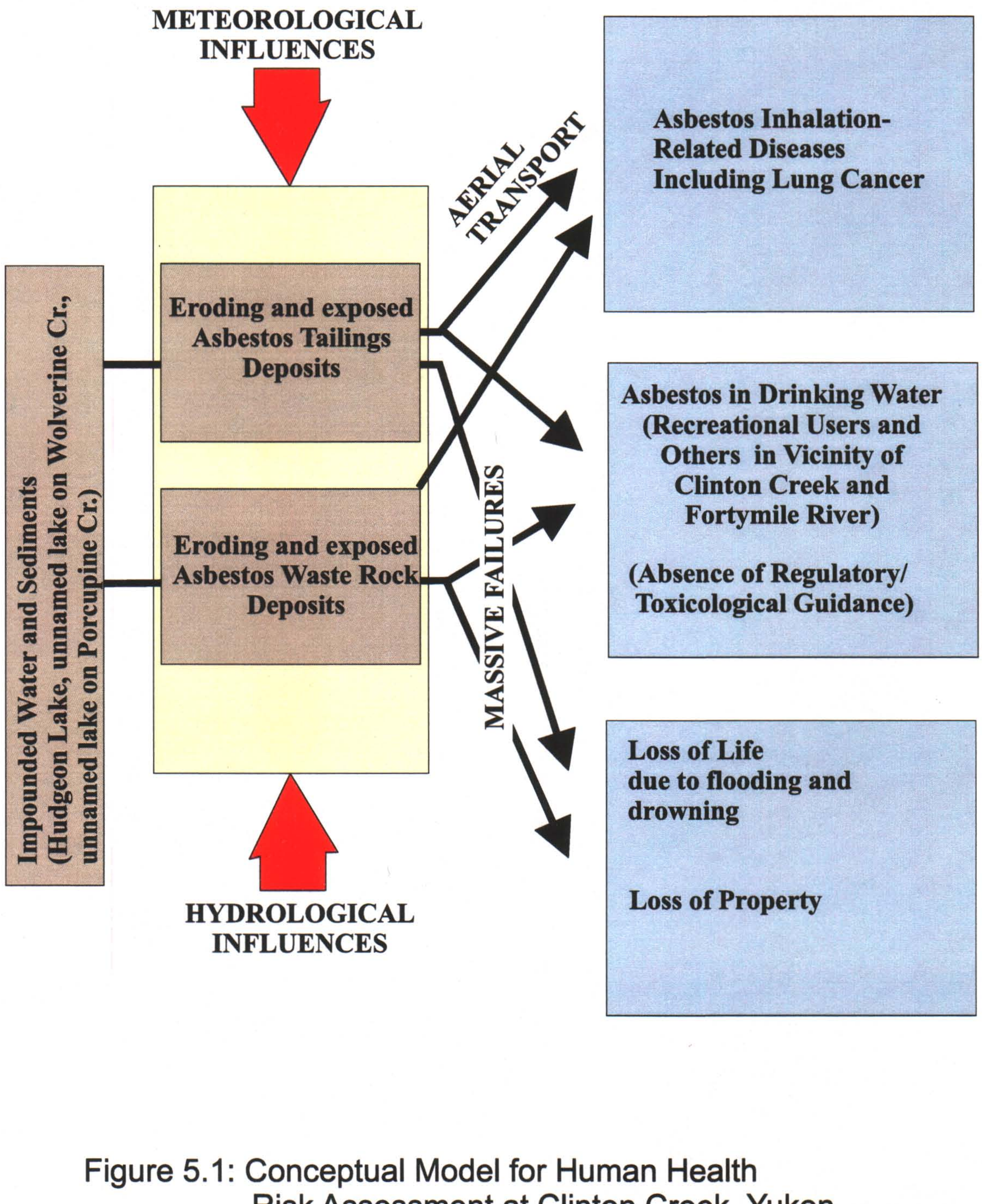

Figure 5.1: Conceptual Model for Human Health Risk Assessment at Clinton Creek, Yukon

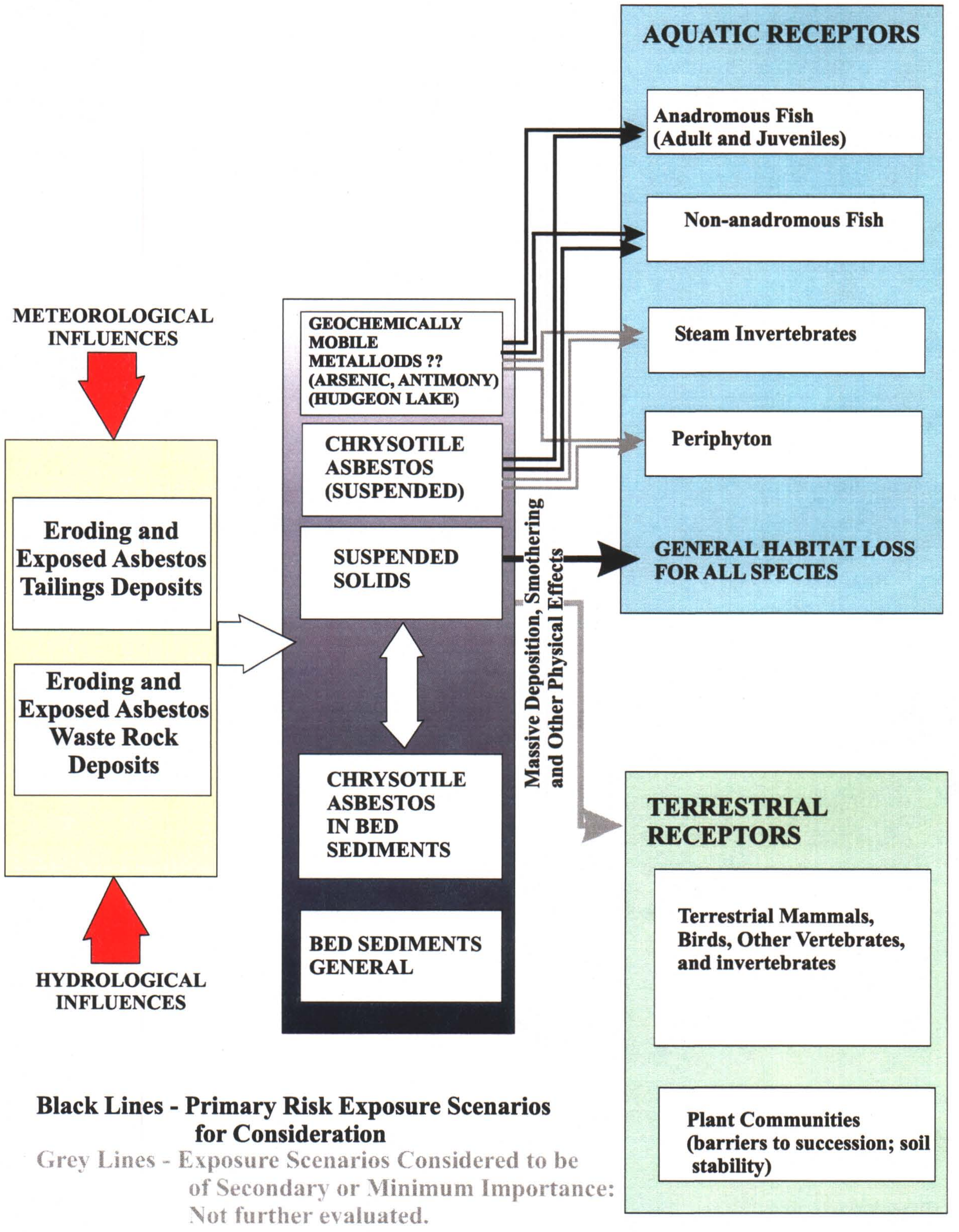

Figure 5.2: Conceptual Model for Ecological Risk Assessment at Clinton Creek, Yukon

5.3 Recommended Assessment and Measurement Endpoints for a More Detailed Assessment of Risk

5.3.1 Asbestos in Air

Air borne asbestos at and near the abandoned mine site is probably of minimum consequence for human health or other vertebrates, but merits some minimum measurements of airborne concentrations during extreme dry, windy periods during the late summer. The relatively rapid formation of a geological crust over old deposits and disturbed areas serves to minimize airborne concentrations of chrysotile asbestos fibres. Observations of mats of chrysotile asbestos in the lower branches of trees, however, at a height corresponding to the height of the winter snow pack, suggests a least some potential for continued mobilization in the terrestrial environment. In addition, large-scale shifting of waste rock and tailings along active slope failures is expected to continuously uncover fresher, less modified, asbestos-containing deposits. Given the known carcinogenicity of inhaled asbestos fibres in humans, a small number of air samples should be collected and compared with acceptable exposure levels in occupational environments.

The actual extent of human exposures is expected to be much less than would occur in an occupational setting, where the daily and long-term duration of inhalation exposures would be much greater. Any preliminary assessment of elevated risks, therefore, should trigger the initiation of a human health risk assessment using more realistic exposure estimates.

5.3.2 Asbestos in Water

The present data are more than sufficient for a detailed assessment of the likely magnitude of exposure to asbestos fibres in water. There is, however, insufficient scientific knowledge for effects characterization in aquatic biota, including fish. The implications of various levels of water-borne chrysotile asbestos cannot presently be ascertained from the existing scientific literature; however, previous reviews have suggested that water-borne asbestos has little if any toxicity to aquatic organisms. The effects assessment should include a detailed literature review of the effects of chrysotile asbestos on salmonids, other fish taxa, and stream invertebrates. It is anticipated that little if new information has been produced within the last few decades, however.

The most direct way to assess the combined effects of chronic mobilization of chrysotile asbestos and other components of suspended sediments in the stream and river environment is through the use of flume experiments, wherein salmon (or trout) juveniles and young adults are exposed to finer grained waste rock and tailings materials using similar exposure regimes as might occur downstream from the minesite. Obvious biological measures of response could include increased mortality, incidence of disease (especially as mediated through skin and gill abrasion), growth, epithelial and gill tissue structure, and various biochemical indicator measures. It will be necessary to ensure the ecological relevance and establishment of field reference sites for such studies, should they be conducted.

5.3.3 Other Suspended Sediment Components

The waste rock and tailings materials include as part of the relatively inert physical make-up both asbestos fibres and other geological materials. Collectively, the geological materials may have a deleterious effect on riverine habitats and species if geological slumping and erosion contribute to excessive sediment loads in the water column and/or excessive smothering of benthic habitats in Clinton Creek, Fortymile River and the Yukon River. The ecosystem elements at risk include (i) salmon spawning habitats and existing eggs in spawning grounds depending on the timing of sediment release, (ii) other benthic invertebrates, (iii) periphyton communities especially in association with decreased light penetration to the stream bed, and (iv) pelagic species that are adversely affected by excessive total suspended solids.

The exposure regimes considered should include various levels of geological instability; e.g. as might be encountered seasonally in an average year, as would occur in the face of an increasingly massive impoundment failure based on geophysical/hydrological risk probability distribution functions, and as might occur during extreme rainfall or snowmelt and flooding event. The degree of sediment release and subsequent riverine fate would be best assessed using a combination of existing data and new measures of particle size distributions and settling properties, in combination with site-specific hydrological and geophysical stability modeling to predict sedimentation across a range of "chronic" to "catastrophic" failure scenarios.

5.3.4 Predicted Smothering of Salmonid Habitat, Including Spawning/Rearing Grounds

As an extension of the preceding, the assessment of salmonid or other fish habitat loss would rely on model predictions of the sedimentation and erosion regimes based on a range of scenarios. The quantification of implications would rely on the existing habitat information as described in Section 4. Ideally, it would be worthwhile to estimate the predicted impact of future loss of salmonid spawning and rearing habitat on watershed wide population estimates, especially for Chinook salmon.

5.3.5 Loss of Terrestrial Vertebrate and Invertebrate Wildlife Downstream From Minesite Following Various Degrees of Catastrophic Failure

This is not considered to be of serious consequence for the long-term integrity of wildlife populations and communities in this part of the Yukon. Even though there is undoubtedly some risk to individuals within wildlife populations, any mortality associated with catastrophic failure is not expected to affect regional populations overall, and individual mortality or impaired fitness would very likely be offset through immigration over time from other areas of the larger ecosystem. One obvious example is the beavers that occur in reaches of Clinton Creek below the abandoned mine site. As mentioned in Section 4, the beavers that have dammed Clinton Creek below the waste rock impoundment are at risk from impoundment failure and massive erosion; however, this would be expected to have little effect on the overall viability of beaver populations.

5.3.6 Risks to Human Life Due to Flooding

Concerns have previously been expressed for risks to human life for individuals caught in the Fortymile Creek and Yukon River flood plains in the event of a massive breach of the waste rock impoundment at the outflow to the Hudgeon River. The site-specific modeling and prediction of hydrological events associated with such a breach, however, has never been conducted. Information provided in this report on the volume and depth distribution of Hudgeon Lake, coupled with information on the geophysical stability of the impoundment as well as watershed hydrology should be combined to provide up-to-date probablistic quantitative estimates of flooding risks. This series of tasks is deemed to be important for a number of risk scenarios, such as loss of salmonid habitat.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Geophysical Stability of Waste Rock and Tailings Deposits, Including Hudgeon Lake

The chronic inputs of asbestos, metals/metalloids, and other chemical substances into the terrestrial and aquatic receiving environment around the abandoned Cassiar Asbestos Company mine and mill site have been characterized in sufficient detail to begin to quantitatively assess the exposure to chronic and long-term gradual environmental perturbations. The probability and projected consequences, however, of various forms of moderate to massive failures of unstable slopes and impoundments which are presently holding back water have not been assessed. It should be noted that UMA (in progress) was initially requested to begin an evaluation of the geophysical stability component of ecological and human health risk. The geophysical stability, especially of impoundments, is the key determinant for what is likely to be the most important drivers of risk: direct fish and fisheries habitat loss through smothering and flooding, and risks to human life and property from a massive flooding event.

An ability to accurately assess the likelihood of different scales of geophysical failure and subsequent consequences for the downstream watershed needs to be developed as part of any effort to assess and manage the risks of the abandoned site. The bathymetry and volume-depth distribution of Hudgeon Lake was determined as an aid to constructing a range of scenarios for massive water release due to a failure of the waste rock impoundment at the lake outlet. This should also allow a better prediction of what will happen if lake water levels are gradually increased or decreased, and if the height of blockage at the valley floor increases over time due to the continuing downslope failure.

6.1.1 Recommendations for Geophysical Evaluations as a Source Term for Risk Assessment

Please refer to UMA (in progress) for detailed recommendations on the next stage. It should be noted, however, that any ecological and human health risk calculations will rely heavily on the following information, which does not presently exist in sufficient detail:

- Predicted short- and long-term fate of –
    - ⇒ Clinton Creek waste rock deposit;
    - ⇒ Porcupine Creek waste rock deposit;
    - ⇒ Snowshoe Pit waste rock deposit; and
    - ⇒ Tailings deposit, including north and south lobe.
- Probability distribution function for different magnitudes of geophysical failure for each of the five deposits.

- Expected downstream fate for different magnitudes of materials release based on particle size and other physical characteristics, as well as site-specific hydrology.

- Scenario analysis for expected range of seasonal and inter-annual variation based on meteorology and hydrology.

- Predicted consequences of various risk management scenarios such as enhanced re-vegetation, other stabilization measures, lowering the levels of impounded water by shunting in a pipe around the blockage, and so on.

6.2 Conclusions on Aquatic Habitat and Fisheries

The most significant changes in fish habitat since 1980 appear to have occurred in the upper reaches of Clinton Creek near the minesite. Continued slumping of waste rock has occurred in Zone 1 making fry accessibility increasingly poor in this area. Noticeable improvements have occurred to fish habitat in Zone 2 with significant re-establishment of riparian vegetation, consolidation of stream flows, and greater stream habitat stability. Habitat conditions in lower zones of Clinton Creek remain relatively stable and comparable to the reference location in Mickey Creek.

- The minnow trap results in the current (1998) study are based solely on one-time sampling events; however, they suggest -

  i) An increase in the resident chinook fry population of Clinton Creek; and

  ii) A possible shift in the composition of resident fry populations from freshwater Arctic Grayling to anadromous chinook salmon since 1980.

- No significant changes in (young-of-the-year) fry size in the Clinton Creek watershed are apparent compared with the 1980 (EVS) study.

- No significant improvements are apparent in the *fall* Arctic grayling population of Hudgeon Lake since 1980. This is suggested by the absence of resident fry in Clinton Creek, questionable water quality conditions in the hypolimnion of the lake, and the lack of any evidence of resident adult fish in the watershed during the 1998 study. More recent investigations by Indian and Northern Affairs (1999) suggest that a small temporary group of summer resident fish (possibly Grayling) may migrate upstream to Hudgeon Lake from Clinton Creek.

- Food productivity (i.e., invertebrates and plankton) for fish in the Clinton Creek watershed appears to be comparable to the 1980 (EVS) investigation, based on preliminary studies in Hudgeon Lake. This would likely support a population of summer resident fish in the lake as suggested above.

6.2.1 Recommendations from Fishery Habitat Study

Based on the above conclusions, the following are provided as recommendations for further investigations addressing fisheries habitat:

- Additional minnow trap sampling in the Clinton Creek watershed during the summer is needed to properly verify changes in salmonid fry species composition in the system and to establish broader seasonally variable population estimates. The trapping should also be expanded to other tributaries feeding into Clinton Creek and within the ecological footprint of the mine site which were not examined during the 1998 study including Porcupine, Eagle and Wolverine Creeks and, possibly, embayments in Hudgeon Lake. Modifications may also be needed to ensure equivalent capture methodology is employed for the study species (Al von Finster, HEB, DFO, pers. comm., 1999);

- Electrofishing during the summer using properly-placed stop nets in different areas of the Clinton Creek watershed is required to verify whether an adult resident or transient fish community (particularly Arctic grayling) is still supported;

- Additional observations of spawning grounds and adult Chinook returns for spawning. These observations should confirm the extent of viable spawning habitat as well as a census of spawning returns in Fortymile River, Clinton Creek, and other tributaries.

- Quantitative assessment of plankton/invertebrate food productivity in summer for fish at different locations in the Clinton Creek watershed including areas mentioned above. This might also include consideration of studies done on a similar stream in a non-glaciated area of the Yukon (Al von Finster, HEB, DFO, pers. comm., 1999);

- Expanded gill net sampling at other locations further into Hudgeon Lake is needed during the summer, and a full range of mesh sizes, to verify whether adult fish populations of grayling or other species are supported. Close monitoring should be employed to ensure no mortality occurs during sampling, in the event that only small fish stocks are present. Sampling might be facilitated in this way by using a floating, monofilament gang net containing a number of panels with graduated mesh sizes (Al von Finster, HEB, DFO, pers. comm., 1999).; and

- Complete assessment of water quality parameters (e.g., dissolved oxygen, pH, temperature, dissolved inorganic substances) is needed throughout Hudgeon Lake to determine whether or not fish can be supported in this system, particularly with respect to high levels of hydrogen sulfide detected in the hypolimnion.

6.3 Conclusions on Terrestrial Habitat Survey

Natural reclamation of both the tailings and waste rock sites at the mine continues to be slow, likely as a result of alkaline and/or serpentine substrates. Reestablishment of vegetation at the tailing site is also undoubtedly hampered by smothering from the finer tailings particles as seen in the adjoining forest, in addition to substrate chemistry (such as lack of plant nutrients and mineral deficiencies) in the tailings material which may affect seedling establishment. The effects of smothering from wind and snow are particularly evident in the forest trees adjoining the site and may represent an on-going (chronic) concern affecting the health of the neighboring forest. This is particularly true of the forest relic situated between the two tailings piles which also serves as a small buffer zone for portions of the aquatic habitat in Wolverine Creek. Establishment of a few isolated trees and other species (primarily grasses) has begun to occur in a few locations near the top of the pile. The factors unique to the establishment of these individual saplings (e.g., soil chemistry) in specific areas of the site should also be investigated in more detail.

The waste rock site appears to be more amenable to the natural establishment of tree species and vegetation in general, which may be due to more favorable soil chemistry for these plants. Establishment may have also been hampered in the past by heavier traffic from mining and other activities as evidenced by the patches of vegetation occurring outside of the main roadways. This may have been compounded by the coarse substrates and other associated nutrient availability factors. Factors unique to the establishment of vegetation at this site should also be investigated in more detail.

The mine site and surrounding areas are used by a wide variety of wildlife. Among these, the beaver colony in Wolverine Creek adjacent to the tailings pile would appear to experience the greatest ecological health risk given their direct and regular contact with tailings materials. The beaver would probably be one of the main "terrestrial" receptors for consideration if an ecological risk assessment for contaminant toxicity or other ecological effects was deemed required for the mine site

6.3.1 Recommendations from Terrestrial Habitat Studies

Based on the above conclusions, the following are provided as recommendations with respect to the terrestrial habitat at the Clinton Creek mine site:

- In lieu of any viable structural engineering solutions for stabilizing the waste rock and tailings areas from chronic or catastrophic failure, the use or promotion of native vegetation including ground cover (such as grasses), and trees to secure the slopes in the tailings and waste rock areas and promote natural regeneration of the mine site should be pursued as a key alternative here. This is also an important consideration at the tailings site where the Wolverine Creek beaver colony may be directly affected.
- In support of the above, proper screening, testing and selection of native plant species and seeding techniques which would most easily establish and colonize the slopes should be investigated. This would start with investigating the factors unique to the establishment of current vegetation in specific areas on the sites, as

well as enhancing the optimal plant nutrient balance and/or physical characteristics in the substrates, if necessary.

- Ways of reducing the direct contact of the Wolverine Creek beaver colony with encroaching materials from the tailings site should be investigated. This might include, for instance, creating a buffer zone between the tailings and the shore of creek using a physical barrier or vegetation.

6.4 Conclusions on Geochemical Stability of Waste Materials and Risk

There are naturally elevated concentrations of most metals and metalloids in the geological strata around the abandoned minesite. Few of the metals/metalloids, however, appear to exist in a form in natural minerals or in residual waste deposits that is amenable to solubilization and biological availability, especially in aquatic systems. Owing to higher than expected detection limits achieved for arsenic and antimony due to the high concentrations of other cations, however, we were unable to ascertain that the dissolved concentrations of these two metalloids were lower than levels that might cause concern.

Aluminum, iron, manganese, and selenium occur in river water in naturally elevated concentrations, even in background reference samples. For aluminum and selenium in particular, the water-borne concentrations exceeded the CCME criteria for the protection of aquatic life in some samples.

6.4.1 Recommendations from Geochemical Stability Studies

- Targeted sampling, with a focus on Hudgeon Lake, should be carried out to assess the water-borne concentrations of arsenic and antimony, using sampling and analytical techniques capable of achieving detection limits of around 1 μg/L, or 0.001 mg/L. Special attention should also be given to lake stratification and geochemical behaviour in a suboxic hypolimnion.

- The tissue concentrations in stream invertebrate and/or fish tissue samples of aluminum and selenium might be assessed as a direct method for ascertaining that these are not bioaccumulated at concentrations that would lead to adverse effects in aquatic biota. We expect that these will have limited bioavailability. If tissue analysis is carried out, it will also be necessary to sample and analyze appropriate reference specimens.

6.5 Conclusions on Ecosystem Components at Risk, Including Humans

As outlined in Section 5, the components of the ecosystem that are deemed to merit further assessment of risks include –

- Anadromous and non-anadromous fish populations and habitat, possibly including fish forage species such as aquatic invertebrates.

Terrestrial ecological receptors, other than humans, can provisionally be excluded from inclusion in a more detailed ecological risk assessment. A limited duration, catastrophic mortality of a small number of individuals from the larger population of mammals, birds, amphibians, plants, or other taxa in the region, would probably not affect the overall viability of plant and wildlife populations. If, however, unique habitats and/or threatened or endangered species are identified in the Clinton Creek or Porcupine Creek watersheds below the abandoned mine site, then additional consideration will need to be given to these terrestrial ecological receptors.

Human health related risks that have not been excluded to the present time, and which merit further examination include –

- Cancer risks due to the inhalation of friable chrysotile asbestos fibres in the terrestrial environment based on occasional site visits;
- Cancer and other health risks from the ingestion of water with elevated levels of chrysotile asbestos fibre levels.; and
- Risk of loss of life or other traumatic injury, or of property damage, due to severe flooding.

6.5.1 Recommendations for Follow-up Risk Assessment Efforts

The "Effects Assessment" portion of an ecological and human health risk assessment generally provides an estimate of the magnitude of exposure to a stressor beyond which deleterious effects have been previously documented. We are presently compiling a literature review of the effects of asbestos in aqueous media, including human drinking water and aquatic environments. There is very little existing information on ecologically relevant effects of exposure to asbestos fibres on aquatic life: Very few scientific studies have ever been completed.

In addition to the recommendations for additional habitat surveys (Sections 6.2.1, 6.3.1), the following additional information would be useful as part of the "Effects Assessment" portion of a detailed risk assessment:

- New studies (using environmentally realistic flume-type mesocosms) on the chronic effects on juvenile and adult salmonids (including Chinook salmon) of water-borne chrysotile asbestos across a range of concentrations;
- New studies on the chronic effects on juvenile and adult salmonids of the combined effects of chrysotile asbestos and suspended solids from the waste rock and tailings deposits;
- Detailed review of the effects of asbestos in drinking water on human health.
- Limited measurements of asbestos fibre concentrations in air around the abandoned open pit mine, and tailings deposits.

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Appendix A: Sampling Locations and Descriptions

APPENDIX A: Sample Locations and Descriptions

A.1. Minnow Trap Locations in Clinton Creek

Location	Description
Zone 1	Just below (SE) of the Hudgeon Lake outlet (Point 0 (km)). GPS Coordinates:64-27-06 N, 140-44-02 W Slumping and erosion of waste rock in this area. Some riparian vegetation including small trees (e.g., poplar, and willow) particularly in the upper portion of the zone near Hudgeon Lake. Erosion of the banks in upper portion has resulted in undercuts forming series of small pools. Narrow canyon in lower portion has cut deep into the waste rock leaving steep scree slopes with exposed faces of bedrock along shore in some places and swift currents; establishment of isolated pockets of shrub vegetation. No evidence of the wiers mentioned in 1980 (EVS, 1981). Canyon area contains no refugia for fry. *Traps*: 2 set up in small quiet pools in under cuts on E & W sides of creek, 40 m S of Hudgeon Lake for ~ 24h
Zone 2	1.5 to 3.5 km downstream from Hudgeon Lake, including confluence of Wolverine Creek GPS Coordinates: 64-26-57 N, 140-42-16 W Coarse rock shoal along W bank at confluence with Wolverine Creek culvert Rock bottom with gravel, cobble and small amount of sand Narrow side channel located 2 m N of confluence Beaver dam ~ 100 m upstream causing overflows and flooding along banks Riparian vegetation includes mixed poplar/willow/spruce and grasses. Channel 5 m wide x 1 m deep; average flow of 1.5 m/sec. *Traps:* 3 set up in quiet pools in undercuts, 1 on E and 2 on W sides of creek respectively, for ~18 h

Location	Description
Zone 3	3.5 to 6 km downstream from Hudgeon Lake, including confluence of Eagle Creek GPS Coordinates: 64-25-58 N, 140-40-08 W Confluence of Eagle Creek, backwater just to south. Coarse sand and pebble banks at confluence with gravel bottom (good spawning areas). Lot's of riparian vegetation including birch, willow, sedge; small amounts of woody debris along W bank. Large pool leading into riffle area. Channel 6-10 m wide x 1-1.2 m deep; average flow of 1 m/sec. *Traps:* 3 set up in quiet pools in undercuts, 1 on E and 2 on W sides of creek respectively, for ~47 h
Zone 4	6 to 7 km downstream from Hudgeon Lake GPS Coordinates: 64-25-51 N, 140-40-03 W Steep ravine on both sides with predominantly undercut banks. Large rocks on streambed, dead trees along foreshore with few side pools. Riparian vegetation includes dense willow, poplar, spruce (further upslope), grass and moss along stream edge. Channel 4-5 m wide x 1 m deep; average flow of 0.7-1m/sec. *Traps:* 3 set up in quiet pools in undercuts, 2 on E and 1 on W sides of creek respectively, for ~18 h
Zone 5	7 to 8 km downstream from Hudgeon Lake, identified but inaccessible for sampling by EVS (1981) GPS Coordinates:64-25-04 N, 140-38-57 W Steep eroded slope along E side, rock bank along W side leading up to steep treed slope Mostly riffling with few pools but lots of undercut bank Banks surrounded by young poplar & birch, some grass and shrub along riparin zone Channel 6 m wide x 0.5 m deep; average flow of 0.4-0.5 m/sec. *Traps:* 3 set up in quiet pools in undercuts, 2 on W and 1 on E sides of creek respectively, for ~45 h

Location	Description
Zone 6	8 to 9.2 km downstream from Hudgeon Lake, above the creek entrance to Fortymile River and the old town site. GPS Coordinates:64-24-28 N, 140-36-52 W 70-100 m downstream from beaver dam just above old bridge crossing to Townsite, steep eroded banks in places Cobble and gravel bed midstream with medium sand/silt along edges Riparian vegetation dominant including willow, alder, birch and sedge Channel 8m wide x 0.5 m deep; average flow of 1m/sec. *Traps:* 3 set up in quiet pools in undercuts, 2 on E and 1 on W sides of creek respectively, for ~18 h
Mosquito Creek	Reference location, ~1 km upstream (SE) of its confluence with Fortymile River (not previously sampled by EVS (1981)) ~1 km upstream from south shore of Fortymile River by road culvert GPS Coordinates: 64-23-30 N, 140-36-31 W Gravel/pebble shoal along centre of creek, streambed coarse gravel and pebbles Pebble shore on W side, E bank undercut Dense riparian vegetation right up to banks including mixed willow, birch and grasses Channel 25 m wide x (average) *Traps:* 2 set up in quiet pools in undercuts, on E and W sides of creek respectively, for ~36 h

A.2. Sediment and Water Samples in Watershed

Sample		Location & Description
Water	**Sediment**	
CLCR-1	CLCR-1S	Southeast side of Hudgeon Lake, below pile of waste rock Coarse sand, and waste rock Field duplicates labeled CLCR-9
CLCR-2	CLCR-2S	Outlet of Hudgeon Lk., north side Coarse sand and gravel
CLCR-3	CLCR-3S	Confluence of Wolverine and Clinton Creek Coarse sand and gravel
CLCR-4	CLCR-4S	Northwest edge of Hudgeon Lake near old water intake site, along east edge of north fork . Sand and gravel with small amount of silt.
CLCR-5	CLCR-5S	Creek on north fork of Hudgeon Lake, 1 km from the water intake point. Sand with organic material
CLCR-6	-	Centre of Hudgeon Lake approximately 1 km west of the outlet into Clinton Creek Unsuccessful attempt to obtain sediment using Petite Ponar grab
CLCR-7	CLCR-7S	West end of Hudgeon Lake, approximately 250 m east of upstream entrance of Clinton Creek into Hudgeon Lake. Black silt, no odour
CLCR-8	-	20 m from the mouth of Bear Creek on southern side of Hudgeon Lake No sediment sample collected
CLCR-9	CLCR-9S	Field duplicate of CLCR-1

Sample		Location & Description
Water	**Sediment**	
CLCR-Z1	CLR-Z1S	Clinton Creek - Zone 1, Just below (SE) of the Hudgeon Lake outlet (Point 0 (km)). GPS Coordinates:64-27-06 N, 140-44-02 W Coarse sand mixed in silt.
CLCR- Z2	CLCR-Z2S	Clinton Creek - Zone 2, 1.5 to 3.5 km downstream from Hudgeon Lake, including confluence of Wolverine Creek GPS Coordinates: 64-26-57 N, 140-42-16 W Rock Bottom with gravel cobble & small amount of sand
CLCR-Z3	CLCR-Z3S	Clinton Creek - Zone 3, 3.5 to 6 km downstream from Hudgeon Lake, near the confluence of Eagle Creek GPS Coordinates: 64-25-58 N, 140-40-08 W Coarse sand and pebble banks with gravel bottom.
CLCR-Z3B	CLCR-Z3BS	Eagle Creek - Zone 3, 35 m upstream of its confluence with Clinton Creek GPS Coordinates: as for CLCR-Z3 Sand, gravel and silt
CLCR-Z4	CLCR-Z4S	Clinton Creek - Zone 4, 6 to 7 km downstream from Hudgeon Lake GPS Coordinates: 64-25-51 N, 140-40-03 W Large rocks on streambed Slight tea colour to water
CLCR-Z5	CLCR-Z5S	Clinton Creek - Zone 5, 7 to 8 km downstream from Hudgeon Lake GPS Coordinates: 64-25-04 N, 140-38-57 W Gravel substrate with some sand. Slight tea colour to water

Sample		Location & Description
Water	**Sediment**	
CLCR-Z6	CLCR-Z6S	Clinton Creek - Zone 6, 8 to 9.2 km downstream from Hudgeon Lake. 10 m upstream of ford crossing to old town site. GPS Coordinates:64-24-28 N, 140-36-52 W Gravel/pebble shoal along centre of creek, streambed coarse gravel and pebbles Slight tea colour to water
CLCR-Z7	CLCR-Z7S	Fortymile River, along SE shore in side channel, ~450 m downstream of Clinton Creek confluence GPS Coordinates:64-24-25 N, 140-35-36 W River ~ 150 m wide at this point, side channel half of this width Large sandy shoal in centre of river, rocky bed with coarse-fine sand underneath Side channel 75 m wide x 25-30 cm deep, velocity 30 cm/sec
CLCR-Z8	CLCR-Z8S	Fortymile River, along NW shore, upstream of Clinton Creek confluence, at SE corner of old town site by pumphouse at base of steep slope GPS Coordinates:64-23-52 N, 140-36-37 W Large rock bottom with coarse-medium sand Channel ~ 150 m wide X 0.5 m deep, velocity 50 cm/sec.
CLCR-Z9	CLCR-Z9S	Mosquito Creek, reference location, ~1 km upstream (SE) of its confluence with Fortymile River (not previously sampled by EVS (1981)) ~1 km upstream from south shore of River by road culvert GPS Coordinates: 64-23-30 N, 140-36-31 W Gravel/pebble shoal along centre of creek, streambed coarse gravel and pebbles

Sample		Location & Description
Water	**Sediment**	
CLWC-1	CLWC-1S	Wolverine Creek, ~ 40 m N.E. and upstream of edge of north lobe tailings pile, in creek widening from beaver dam, 150 m north of "Wolverine Lake" GPS Coordinates: 64-27-41 N, 140-42-31 W Series of active beaver dams (and beaver sightings) in area resulting in extensive flooding of adjoining natural spruce/willow forest; some dead trees from flooding along periphery. Very mossy substrate with number of springs daylighting in area. Samples taken next to beaver lodge. Black organic silt sediment. Tea-coloured water.
CLWC-2	CLWC-2S	Wolverine Creek at S end (outlet) of "Wolverine Lake" by active beaver dam, near SE edge of S lobe of tailings GPS Coordinates: 64-27-29 N, 140-42-40 W Brown to tea-coloured water.
CLWC-3	CLWC-3S	Field duplicate of WC-2
CLWC-4	CLWC-4S	Wolverine Creek approximately 1 km downstream from edge of south lobe of tailings just before site of old stream crossing bridge GPS Coordinates: 64-27-10 N, 140-42-17 W Samples taken from stream side of flood plain formed from siltation of tailings Coarse sand substrate with light green colour
	CLWC-5	Sediment from Wolverine Creek, 3 m from culvert on road to waste rock site. Light green layer on sandy sediment

A.3. Soil/Substrate Samples from Mill/Tailings Site

Sample	Location and Description
CLMS-1	Top of tailings site, west end of S lobe in low-lying wet area approximately 250 m southwest of water tower in direct line with cable towers, green rocks nearby. GPS Coordinates: 64-27-33 N, 140-43-25 W Vegetation scarce, mostly moss and a few grasses Substrate composed of sand/silt soil mixed with asbestos fibres. Vegetation survey and plant sampling conducted. Assorted metal debris, wood and cables scattered in area.
CLMS-2	Tailings site, base of south lobe along south end near forest edge, in drainage channel curving around base of pile, 3 m from the edge of the tailings pile. GPS Coordinates: 64-27-25 N, 140-43-18 W Evidence of dead vegetation (particularly spruce) along forest periphery of this location. Tailings coating on standing trees in forest just to the south. Evidence of moose tracks in this area. Fine sand-silt soil (tailing fines) Vegetation survey and plant sampling conducted.
CLMS-3	Peak on south lobe of tailings site towards southeast end overlooking Wolverine Creek to the southeast, approximately 600m southwest of mill site tanks GPS Coordinates: 64-27-28 N, 140-43-17 W No plants Coarse to fine tailings.
CLMS-4	Substrate profile of CLMS-3 taken at 30 – 40 cm depth Coarse to fine tailings.
CLMS-5	Top of tailings site ~ 100 m NE of S lobe peak in low-lying flat area between the N and S lobes in area of darker soil GPS Coordinates: 64-23-32 N, 140-43-18 W Relatively large patch of scrub vegetation (20 X40 m). Dark mica-coloured soil mixed with tailings sand. Vegetation survey and plant sampling conducted.

Sample	Location and Description
CLMS-6	Tailings site on northern slope of north lobe approximately halfway between top and bottom (near forest edge) of pile along drainage channel. GPS Coordinates: 64-27-43 N, 140-43-23 W Vegetation very sparse and limited to a few grasses (e.g., *Poa* sp.) Moose tracks noted at top of this drainage area Tailings, fine sand/silt with small pebbles Vegetation survey conducted, no plant sampling.
CLMS-7	Tailings site on north slope of north lobe, further along same drainage path as CLMS-6 at bottom of pile along forest edge (near forest edge) of pile. GPS Coordinates: 64-27-43 N, 140-43-22 W Vegetation sparse. Mostly grass, *Hordeum jubatum* (wild barley). Fine grained substrate. Vegetation survey and plant sampling conducted.
CLMS-8	Top of tailings site, 2 m from base of west edge of peak on north lobe, 20 m southwest of mixed willow/poplar/birch forest edge, 50 m northeast of tramway receiving tower and 6 m east of old scrap pile of metal siding. Wood and metal debris scattered in the area. GPS Coordinates: 64-27-37 N, 140-43-29 W Vegetation sparse, mostly grasses. Vegetation survey and plant sampling conducted. Fine material
CLMS-9	Tailings site at peak of north lobe in rocky erosional area on eastern side, GPS Coordinates: 64-27-39 N, 140-43-27 W Vegetation sparse, young spruce sapling nearby. Coarse sand mixed with small rocks, stones and tailings.
CLMS-10	Field duplicate of CLMS-9

Sample	Location and Description
CLMS-11	Along southeast slope of south lobe, approximately 2/3 of the way downslope (200 m from peak, 300 m from toe) and approximately 20 m from forest edge to the south; intersected by side access cat track road from the south GPS Coordinates: 64-27-24 N, 140-43-01 W No vegetation. Coarse sand with large-sized gravel.
CLMS-12	Bottom of slope along S lobe of tailing site in flat outwash area, ~70 m S of "Wolverine Lake" & 70 m W of Wolverine Cr. GPS Coordinates: 64-27-27 N, 140-42-46 W No vegetation. Light brown sand and fine material
CLMS-13	At the base of forested area between the north and south lobes, approximately 5 m west of the edge of pond along Wolverine Creek. GPS Coordinates: 64-27-34 N, 140-42-43 W Spruce forest with rich undergrowth and young saplings in area Soil sample taken from exposed (eroded) native soil profile exposing organic soil layer and native till underneath; background sample taken from underlying native till (10-15 cm) Vegetation survey and plant sampling conducted.
CLMS-14	South side of concrete foundation on the southern edge of Mill site, near 3 stand pipes. Middle pipe contained an oily material. Sample collected from the base of middle stand pipe. Mostly tailings.

A.4. Soil/Substrate Samples from Mine/Waste Rock Site

Sample	Location and Description
CLWR-1	Base of most westerly portion of pile near Hudgeon Lake in outwash area ~ 6 m from toe and ~ 80 km SE of mouth of lake outlet into Clinton Creek GPS Coordinates: 64-27-03 N, 140-43-56 W Vegetation sparce, consisting of mostly foxtail and other grasses; young balsam poplar scattered through area. Saturated black silt-sand soil. Vegetation survey and plant sampling conducted.
CLWR-2	Top of W end of tailings pile by Marker Target #20A in rocky area ~ 750 m west of Porcupine Pit. GPS Coordinates: 64-27-02 N, 140-43-39 W Vegetation scarce, mostly spruce seedlings and grasses; young stand of poplar to the west. Rocky area with dark shale; coarse sand and gravel. Vegetation survey conducted, no plant sampling.
CLWR-3	On N slope (2/3 way up) of W end of waste rock pile ~250 m S of Clinton Creek canyon area (Zone 1) and ~100 m S of CLWR-2, 15 m above untagged target marker, 200 m E of Hudgeon Lake.
CLWR-4	Field duplicate of CLWR-3
CLWR-5	Open pit site at end of access road near base at south end. Vegetation scarce with exception of a few grasses. Fine silt sediment, asbestos fibres visible on the bottom of the lake. Asbestos-bearing rock everywhere Water: clear aquamarine blue Vegetation survey and plant sampling conducted.
CLWR-6	Open mine pit at base of soft orange mineral intrusion (one of many) in E wall along mine access road. Similar to some areas of waste rock pile on E side of site. No vegetation present. Orange sand-like consistency to substrate.

Sample	Location and Description
CLWR-7	Porcupine Creek in mudflat along N side of creek widening. Directly below cliff leading up to chrusher building situated directly to west. Creek opening ~ Water sample taken from creek 1-2 m below outlet from lake (creek opening), ~ 6 m to NE of mudflat. Asbestos fibres visible was sediment
CLWR-7S	Sediment sample taken from same location in flooded portion of mudflat at NW corner of lake. No vegetation present on mudflat. Sediment muddy silt with dark-gray organic matter and visible asbestos fibres.
CLWR-8	Area of green waste rock above Clinton Creek road ~ 750 m N of west mine pit and ~100 m S of Clinton Cr. Canyon and ~ 30 m SW of target marker. Asbestos fibres visible. No vegetation present in area. Green rocks underlain with coarse sand.
CLWR-9	Field duplicate.
CLWR-10	Green waste rock area, rich in asbestos fibres along north ridge of waste rock pile 40 m above Hudgeon Lake access road ~ 80 m S of Clinton Cr. Ravine, 300 m E of Hudgeon Lake outlet and 60 m W of target marker. No vegetation present.
CLWR-11	Drainage channel running between N. edge of W waste rock pile and S edge of Hudgeon Lake access road. Drainage may flow over road during extremely high water flow periods. Drainage flows down to old bridge crossing at Clinton Creek. Site located 1/3 way up access road from bridge towards Hudgeon Lake. Vegetation sparce consisting of grasses and a few flowering plants. Dark medium-brown sand and silt Vegetation survey and plant sampling conducted.

Sample	Location and Description
CLWR-12	~ 1 m from toe of mid-section of waste rock pile along pebble floodplain of Clinton Creek, ~ 500 m SW of old crossing bridge site, in drainage channel. Vegetation sparce consisting of grasses (foxtail) and spruce seedlings. Saturated black silty mud. Vegetation survey and plant sampling conducted.
CLWR-13	Natural spring from the side of embarkment along Clinton Creek, approximately 40 m from the outlet. Colourless water but rocks stained brown and covered with green algae.
CLWR-14	Drainage at toe of east end of waste rock pile leading out to high water floodplain of Clinton Creek, ~ 60 m SE of bridge crossing site and 7 m from toe of pile. No vegetation in immediate area. Black silt
CLWR-15	Field duplicate of CLWR-11

A.5. Background Samples

Sample	Location and Description
CLBK-1	Background sample taken from undercut area from land slide along N site of Hudgeon Lake access road ~ 150 m NE of Wolverine Creek and ~ 600 m by road (SE) from waste rock bridge crossing site Moderate cover of vegetation consisting of cinquefoil, ryegrass, spruce and willow in vicinity. Coarse sandy brown soil underlying ~ 5-10 cm organic layer of moss. Sample taken from till layer. No vegetation survey or plant samples collected.
CLBK-2	Background sample taken from land slide area along access road ~ 1.2 km (SE) from waste rock bridge crossing site Similar vegetation to CLBK-1 Black native coarse sand material with stones. No vegetation survey or plant samples collected.
CLBK-3	Background sample taken from eroded area below native green rock material along access road ~1.4 km (SE) from waste rock bridge crossing site. Vegetation moderate consisting of young spruce saplings, willow & birch. Coarse sand with some organic material. No vegetation survey or plant samples collected.
CLBK-4	Background sample taken ~ 1 m from edge of roadway on NE side of access road ~ 2.7 km (SE) from waste rock bridge crossing site. Vegetation moderate along edge of spruce forest consisting of grasses and balsam poplar. Sandy soil. Vegetation survey and plant sampling conducted.

Appendix B: Aquatic Data, Vegetation Survey Data and Wildlife Sitings

A.6. Vegetation Samples

A.6.1 Tailings (Mill) Site

Shoot Sample	Root Sample	Location and Survey
CLMS-1	CLMS1-R	*Hordeum jubatum* (wild barley) sample
CLMS-2	CLMS2-R	*Hordeum jubatum* (wild barley) sample
CLMS-3	CLMS3-R	*Hordeum jubatum* (wild barley) sample
CLMS-7	CLMS-7R	*Hordeum jubatum* (wild barley) sample
CLMS-8	CLMS8-R	*Hordeum jubatum* (wild barley) sample
CLMS-13	CLMS-13R	*Hordeum jubatum* (wild barley) sample

A.6.2 Waste Rock (Mine) Site

Shoot Sample	Root Sample	Location and Survey
CLWR-1	CLWR-1R	*Hordeum jubatum* (wild barley) sample
CLWR-3/4	CLWR-3/4R	*Hordeum jubatum* (wild barley) sample
CLWR-5	CLWR-5R	*Hordeum jubatum* (wild barley) sample
CLWR-11	CLWR-12R	*Hordeum jubatum* (wild barley) sample
CLWR-12	CLWR-12R	*Hordeum jubatum* (wild barley) sample

A.6.3 Background

Shoot Sample	Root Sample	Location and Survey
WC-4	WC-4R	*Hordeum jubatum* (wild barley) sample from edge of Wolverine Creek.
CLBK-4	CLBK-4R	*Hordeum jubatum* (wild barley) sample along edge of access road to mine site

APPENDIX B-1: Minnow Trap Survey Data

Zone	Sample	Species	Sp. Code	Lamellae Extracted	Length (cm)	Year Class'97
6	6-1	Chinook	OT	n	8.60	0+
6	6-2	Chinook	OT	n	7.60	0+
6	6-3	Chinook	OT	n	7.60	0+
6	6-4	Chinook	OT	n	7.80	0+
6	6-5	Chinook	OT	n	7.70	0+
6	6-6	Chinook	OT	n	7.85	0+
6	6-7	Chinook	OT	n	8.15	0+
6	6-8	Chinook	OT	n	7.00	0+
6	6-9	Chinook	OT	n	7.30	0+
6	6-10	Chinook	OT	n	7.75	0+
6	6-11	Chinook	OT	y	8.55	0+
6	6-12	Chinook	OT	y	8.75	0+
6	6-13	Chinook	OT	y	8.40	0+
6	6-14	Chinook	OT	y	8.35	0+
6	6-15	Chinook	OT	Released		0+
6	6-15	Chinook	OT	Released		0+
6	6-16	Chinook	OT	Released		0+
5	5-1	Chinook	OT	n	8.30	0+
5	5-2	Chinook	OT	n	8.30	0+
5	5-3	Chinook	OT	n	8.10	0+
5	5-4	Chinook	OT	n	8.45	0+
5	5-5	Chinook	OT	n	8.45	0+
5	5-6	Chinook	OT	n	8.90	0+
5	5-7	Chinook	OT	n	8.50	0+
5	5-8	Chinook	OT	y	9.10	0+
5	5-9	Chinook	OT	y	8.65	0+
5	5-10	Chinook	OT	y	8.85	0+
5	5-11	Chinook	OT	y	8.90	0+
5	5-12	Chinook	OT	Released		
5	5-13	Sculpin	CB	Released	4.00	
4	4-1	Chinook	OT	y	8.00	0+
4	4-2	Chinook	OT	y	8.85	0+
4	4-3	Chinook	OT	y	9.00	0+
4	4-4	Chinook	OT	n	8.35	0+
4	4-5	Chinook	OT	n	7.55	0+
4	4-6	Chinook	OT	n	8.11	0+

OT = *Oncorhynchus tshawytscha* (Chinook Salmon) CC = *Cottus cognatus* (Slimy Sculpin)

Appendix B-1: Minnow Trap Survey Data (Continued)

Zone	Sample	Species	Sp. Code	Lamellae Extracted	Length (cm)	Year Class'97
3	3-1	Chinook	OT	n	7.75	0+
3	3-2	Chinook	OT	n	8.01	0+
3	3-3	Chinook	OT	n	7.50	0+
3	3-4	Chinook	OT	n	7.95	0+
3	3-5	Chinook	OT	n	7.01	0+
3	3-6	Chinook	OT	y	8.10	0+
3	3-7	Chinook	OT	y	8.50	0+
3	3-8	Chinook	OT	y	8.80	0+
3	3-9	Chinook	OT	n	7.90	0+
3	3-10	Chinook	OT	n	8.60	0+
3	3-11	Chinook	OT	Released		0+
3	3-12	Chinook	OT	Released		0+
3	3-13	Chinook	OT	Released		0+
3	3-14	Chinook	OT	Released		0+
3	3-15	Chinook	OT	Released		0+
3	3-16	Chinook	OT	Released		0+
3	3-17	Chinook	OT	Released		0+
3	3-18	Chinook	OT	Released		0+
3	3-19	Chinook	OT	Released		0+
3	3-20	Sculpin	CB	Released		
3	3-21	Sculpin	CB	Released		
3	3-22	Sculpin	CB	Released		
3	3-23	Sculpin	CB	Released		
2	2-1	Chinook	OT	n	8.85	0+
2	2-2	Chinook	OT	n	8.75	0+
2	2-3	Chinook	OT	n	8.85	0+
2	2-4	Chinook	OT	n	8.40	0+
2	2-5	Chinook	OT	n	8.60	0+
2	2-6	Chinook	OT	y	9.30	0+
2	2-7	Chinook	OT	y	9.30	0+
2	2-8	Chinook	OT	y	9.90	0+
2	2-9	Chinook	OT	n	8.40	0+
2	2-10	Chinook	OT	n	9.40	0+
2	2-11	Chinook	OT	Released		0+
2	2-12	Chinook	OT	Released		0+
2	2-13	Chinook	OT	Released		0+
2	2-14	Sculpin	CC	Released		
2	2-15	Sculpin	CC	Released		
2	2-16	Sculpin	CC	Released		

OT = *Oncorhynchus tshawytscha* (Chinook Salmon) CC = *Cottus cognatus* (Slimy Sculpin)

Appendix B-1: Minnow Trap Survey Data (Continued)

Zone	Sample	Species	Sp. Code	Lamellae Extracted	Length (cm)	Year Class'97
1	-	-	-	-	-	-
m	m-1	Chinook	OT	y	11.95	0+
m	m-2	Chinook	OT	y	10.20	0+
m	m-3	Chinook	OT	y	8.65	0+
m	m-4	Chinook	OT	n	8.10	0+
m	m-5	Chinook	OT	n	8.50	0+
m	m-6	Chinook	OT	n	8.40	0+
m	m-7	Chinook	OT	n	8.30	0+
m	m-8	Chinook	OT	n	8.70	0+
m	m-9	Chinook	OT	n	8.20	0+
m	m-10	Chinook	OT	n	8.80	0+
m	m-11	Chinook	OT	n	8.20	0+
m	m-12	Chinook	OT	Released		
m	m-13	Chinook	OT	Released		
m	m-14	Chinook	OT	Released		
m	m-15	Chinook	OT	Released		
m	m-16	Chinook	OT	Released		
m	m-17	Chinook	OT	Released		
m	m-18	Chinook	OT	Released		
m	m-19	Chinook	OT	Released		
m	m-20	Chinook	OT	Released		
m	m-21	Chinook	OT	Released		
m	m-22	Chinook	OT	Released		
m	m-23	Chinook	OT	Released		
m	m-24	Chinook	OT	Released		
m	m-25	Chinook	OT	Released		
m	m-26	Chinook	OT	Released		
m	m-27	Chinook	OT	Released		
m	m-28	Chinook	OT	Released		

OT = *Oncorhynchus tshawytscha* (Chinook Salmon)

CC = *Cottus cognatus* (Slimy Sculpin)

M = Mosquito Creek (reference lake)

APPENDIX B-2: Ground Vegetation Survey Data

Species (% Cover) / *Site/Location*	Moss	Hordeum jubatum	Grass sp.	Poa sp. (wide pannicle grass)	Leguminosae	Picea sp. Seedling	Epilobium sp.	Draba sp.	Taraxacum sp.	Potentilla sp.	Rye Grass	Populus balsamifera	Total Cover (%)	Species Richness
Tailings (Mill) Site														
CLMS-1	1	10	5										16	3
CLMS-2		25											25	1
CLMS-3/4													0	0
CLMS-5	60			10	30								100	3
CLMS-6				5									5	1
CLMS-7		25											25	1
CLMS-8		10	10	5									25	3
CLMS-9/10													0	0
CLMS-11													0	0
CLMS-12													0	0
												Mean	**19.6**	**1.2**
Waste Rock (Mine) Site														
CLWR-1		25	1										26	2
CLWR-2		2				5		1					8	3
CLWR-3/4		25											25	1
CLWR-5		10											10	1
CLWR-6													0	0
CLWR-7													0	0
CLWR-8/9													0	0
CLWR-10													0	0
CLWR-11		10	5						2				17	3
CLWR-12		25				5							30	2
CLWR-13													0	0
CLWR-14													0	0
												Mean	**9.67**	**1.0**
Background														
CLMS-13													0	0
CLBK-1													0	0
CLBK-2										x	x		0	0
CLBK-3						x							0	0
CLBK-4		30	5									10	45	3
												Mean	**9**	**0.6**

Appendix B-3: Wildlife Observations and Sitings

Date	Location	Observations/Sitings
Sept. 10/98	Hudgeon Lake	Raptor (hawk) circling overhead in the morning Flock of waterfowl (~12) taking off from centre of lake in the afternoon which subsequently
	Campsite by town site maintenance garage	Owl calls heard from various locations in surrounding forest at dusk
	Waste rock site by Hudgeon Lake	Numerous moose tracks in area
	Clinton Creek, N of its confluence with Wolverine Creek	Large active beaver dam
Sept. 11/98	Along mine access road near townsite	Raven flying overhead in late afternoon Owl flying overhead in early evening (possibly the same heard the night before)
Sept. 12/98	Tailings (mill) site at base of S. lobe along S.E. side at forest edge	Numerous moose tracks in area, probably common all over site, particularly along side slopes adjacent to forest edge.
	Tailings site at N. lobe	Moose tracks noted near top of slope
	East end of Hudgeon Lake near mouth of Clinton Creek	Approximately seven mallard ducks resting in vicinity near shore in the morning.
	Along mine access road halfway between town and mine sites	Snowshoe hare sited along road at a few locations in afternoon
	Wolverine Creek below N. lobe of tailings site	System of three active beaver dams and lodges in area, two beavers sighted in separate adjoining pools
Sept. 13/98	Waste rock site near open mining pit	Bald eagle circling high over Clinton Creek in the morning

Appendix C-1:
ASL Chemical Analysis Report for Water Samples

1988 Triumph Street, Vancouver, B.C., Canada V5L 1K5

analytical service laboratories ltd.

FAX: (604) 253-6700 TEL: (604) 253-4188

CHEMICAL ANALYSIS REPORT

Date: October 5, 1998

ASL File No. J8624

Report On: Yukon Water Analysis

Report To: **Royal Roads University**
Applied Research Division
2005 Sooke Road
Victoria, BC
V9B 5Y2

Attention: **Dr. Matthew Dodd**, Professor

Received: September 16, 1998

ASL ANALYTICAL SERVICE LABORATORIES LTD.
per:

Frederick Chen, B.Sc. - Manager, Special Projects
Brent A. Makelki, B.Sc. - Supervisor, Client Services

RESULTS OF ANALYSIS - Water

File No. J8624

			CLCR-1	CLCR-2	CLCR-3	CLCR-4	CLCR-5
			98 09 13 10:15	98 09 10 11:05	98 09 11 16:30	98 09 10 14:20	98 09 10 16:10
Dissolved Anions							
Alkalinity-Total		CaCO3	-	105	-	-	101
Bromide	Br		-	<0.5	-	-	<0.5
Chloride	Cl		-	<0.5	-	-	<0.5
Fluoride	F		-	0.13	-	-	0.19
Sulphate	SO4		-	110	-	-	61
Nutrients							
Nitrate Nitrogen		N	-	0.2	-	-	<0.1
Nitrite Nitrogen		N	-	<0.1	-	-	<0.1
Total Metals							
Aluminum	T-Al		0.059	0.067	0.061	0.063	0.066
Antimony	T-Sb		<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	T-As		<0.2	<0.2	<0.2	<0.2	<0.2
Barium	T-Ba		0.05	0.05	0.05	0.05	0.03
Beryllium	T-Be		<0.005	<0.005	<0.005	<0.005	<0.005
Boron	T-B		<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	T-Cd		<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Calcium	T-Ca		46.8	46.7	48.3	45.4	32.1
Chromium	T-Cr		<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	T-Co		<0.01	<0.01	<0.01	<0.01	<0.01
Copper	T-Cu		0.02	<0.01	<0.01	<0.01	<0.01
Iron	T-Fe		0.23	0.25	0.27	0.24	0.17
Lead	T-Pb		<0.001	<0.001	<0.001	<0.001	<0.001
Magnesium	T-Mg		26.0	27.1	27.7	26.3	21.9
Manganese	T-Mn		0.110	0.118	0.108	0.107	0.010
Mercury	T-Hg		<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	T-Mo		<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	T-Ni		<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	T-Se		0.0014	<0.001	0.0012	0.0009	<0.001
Silver	T-Ag		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Thallium	T-Tl		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Uranium	T-U		0.00141	0.00151	0.00149	0.00150	0.00159
Zinc	T-Zn		<0.005	<0.005	<0.005	<0.005	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water File No. J8624

			CLCR-6	CLCR-6A	CLCR-7	CLCR-9	CLCR-Z6
			98 09 10 17:00	98 09 11 11:00	98 09 10 17:15	98 09 13 10:20	98 09 11 14:05
Dissolved Anions							
Alkalinity-Total		CaCO3	102	337	98	-	120
Bromide	Br		<0.5	<0.5	<0.5	-	<0.5
Chloride	Cl		<0.5	2.2	<0.5	-	0.7
Fluoride	F		0.14	0.26	0.17	-	0.18
Sulphate	SO4		111	307	106	-	148
Nutrients							
Nitrate Nitrogen		N	0.2	<0.1	0.2	-	0.2
Nitrite Nitrogen		N	<0.1	<0.1	<0.1	-	<0.1
Total Metals							
Aluminum	T-Al		0.062	0.08	0.123	0.059	0.220
Antimony	T-Sb		<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	T-As		<0.2	<0.2	<0.2	<0.2	<0.2
Barium	T-Ba		0.05	0.11	0.05	0.05	0.05
Beryllium	T-Be		<0.005	<0.005	<0.005	<0.005	<0.005
Boron	T-B		<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	T-Cd		<0.0002	<0.0004	<0.0002	<0.0002	<0.0002
Calcium	T-Ca		45.0	122	45.7	44.9	53.5
Chromium	T-Cr		<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	T-Co		<0.01	<0.01	<0.01	<0.01	<0.01
Copper	T-Cu		<0.01	<0.01	<0.01	<0.01	<0.01
Iron	T-Fe		0.24	0.94	0.26	0.21	0.42
Lead	T-Pb		<0.001	<0.002	<0.001	<0.001	<0.001
Magnesium	T-Mg		26.3	67.7	25.8	25.7	35.8
Manganese	T-Mn		0.117	2.70	0.112	0.111	0.149
Mercury	T-Hg		<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	T-Mo		<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	T-Ni		<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	T-Se		<0.001	<0.002	0.0011	0.0013	0.0011
Silver	T-Ag		<0.0001	<0.0002	<0.0001	<0.0001	<0.0001
Thallium	T-Tl		<0.0001	<0.0002	<0.0001	<0.0001	<0.0001
Uranium	T-U		0.00148	0.00231	0.00145	0.00141	0.00142
Zinc	T-Zn		<0.005	<0.005	<0.005	<0.005	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

File No. J8624

			CLCR-Z3B	CLCR-Z8	CLMS-1	CLWC-1	CLWC-2
			98 09 11 15:45	98 09 11 07:45	98 09 12 10:45	98 09 12 18:05	98 09 12 19:00
Dissolved Anions							
Alkalinity-Total		CaCO3	-	-	-	87	88
Bromide	Br		-	-	-	<0.5	<0.5
Chloride	Cl		-	-	-	0.6	0.6
Fluoride	F		-	-	-	0.14	0.14
Sulphate	SO4		-	-	-	124	128
Nutrients							
Nitrate Nitrogen		N	-	-	-	<0.1	<0.1
Nitrite Nitrogen		N	-	-	-	<0.1	<0.1
Total Metals							
Aluminum	T-Al		0.98	0.28	0.006	0.246	0.193
Antimony	T-Sb		<0.2	<0.2	<0.2	<0.2	<0.2
Arsenic	T-As		<0.2	<0.2	<0.2	<0.2	<0.2
Barium	T-Ba		0.08	0.04	0.04	0.05	0.05
Beryllium	T-Be		<0.005	<0.005	<0.005	<0.005	<0.005
Boron	T-B		<0.1	<0.1	0.6	<0.1	<0.1
Cadmium	T-Cd		<0.0002	<0.0002	<0.0004	<0.0002	<0.0002
Calcium	T-Ca		41.8	21.4	6.69	45.2	41.7
Chromium	T-Cr		<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	T-Co		<0.01	<0.01	<0.01	<0.01	<0.01
Copper	T-Cu		<0.01	<0.01	<0.01	<0.01	<0.01
Iron	T-Fe		0.66	0.36	<0.03	0.39	0.34
Lead	T-Pb		<0.001	<0.001	<0.002	<0.001	<0.001
Magnesium	T-Mg		14.8	6.6	150	29.0	28.3
Manganese	T-Mn		0.040	0.017	<0.005	0.091	0.070
Mercury	T-Hg		<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	T-Mo		<0.03	<0.03	<0.03	<0.03	<0.03
Nickel	T-Ni		<0.05	<0.05	<0.05	<0.05	<0.05
Selenium	T-Se		0.0023	<0.001	0.0024	<0.001	<0.001
Silver	T-Ag		<0.0001	<0.0001	<0.0002	<0.0001	<0.0001
Thallium	T-Tl		<0.0001	<0.0001	<0.0002	<0.0001	<0.0001
Uranium	T-U		0.00078	0.00059	<0.00002	0.00184	0.00176
Zinc	T-Zn		<0.005	<0.005	<0.005	<0.005	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

File No. J8624

			CLWC-3	CLWR-13	CLWR-7
			98 09 12 19:05	98 09 13 17:00	98 09 13 15:15
Dissolved Anions					
Alkalinity-Total		CaCO3	86	-	223
Bromide	Br		<0.5	-	<0.5
Chloride	Cl		0.6	-	0.7
Fluoride	F		0.14	-	0.30
Sulphate	SO4		127	-	900
Nutrients					
Nitrate Nitrogen		N	<0.1	-	0.5
Nitrite Nitrogen		N	<0.1	-	<0.1
Total Metals					
Aluminum	T-Al		-	0.010	0.006
Antimony	T-Sb		-	<0.2	<0.2
Arsenic	T-As		-	<0.2	<0.2
Barium	T-Ba		-	0.06	0.02
Beryllium	T-Be		-	<0.005	<0.005
Boron	T-B		-	<0.1	<0.1
Cadmium	T-Cd		-	<0.001	<0.001
Calcium	T-Ca		-	141	270
Chromium	T-Cr		-	<0.01	<0.01
Cobalt	T-Co		-	<0.01	<0.01
Copper	T-Cu		-	<0.01	<0.01
Iron	T-Fe		-	1.21	<0.03
Lead	T-Pb		-	<0.005	<0.005
Magnesium	T-Mg		-	130	123
Manganese	T-Mn		-	1.18	<0.005
Mercury	T-Hg		-	<0.00005	<0.00005
Molybdenum	T-Mo		-	<0.03	<0.03
Nickel	T-Ni		-	<0.05	<0.05
Selenium	T-Se		-	<0.005	0.0081
Silver	T-Ag		-	<0.0005	<0.0005
Thallium	T-Tl		-	<0.0005	<0.0005
Uranium	T-U		-	0.00040	0.00467
Zinc	T-Zn		-	<0.005	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water File No. J8624

		CLCR-1	CLCR-2	CLCR-9	CLCR-Z6
		98 09 13 10:15	98 09 10 11:05	98 09 13 10:20	98 09 11 14:05
Dissolved Metals					
Aluminum	D-Al	0.103	0.050	0.092	0.048
Antimony	D-Sb	<0.2	<0.2	<0.2	<0.2
Arsenic	D-As	<0.2	<0.2	<0.2	<0.2
Barium	D-Ba	0.05	0.05	0.05	0.05
Beryllium	D-Be	<0.005	<0.005	<0.005	<0.005
Boron	D-B	<0.1	<0.1	<0.1	<0.1
Cadmium	D-Cd	<0.0002	<0.0002	<0.0002	<0.0002
Calcium	D-Ca	45.2	47.8	46.1	53.2
Chromium	D-Cr	<0.01	<0.01	<0.01	<0.01
Cobalt	D-Co	<0.01	<0.01	<0.01	<0.01
Copper	D-Cu	<0.01	<0.01	<0.01	<0.01
Iron	D-Fe	0.25	0.23	0.22	0.23
Lead	D-Pb	<0.001	<0.001	<0.001	<0.001
Magnesium	D-Mg	26.2	27.7	26.4	35.7
Manganese	D-Mn	0.110	0.130	0.111	0.130
Mercury	D-Hg	<0.00005	<0.00005	<0.00005	<0.00005
Molybdenum	D-Mo	<0.03	<0.03	<0.03	<0.03
Nickel	D-Ni	<0.05	<0.05	<0.05	<0.05
Selenium	D-Se	0.0012	<0.001	0.0011	0.0010
Silver	D-Ag	<0.0001	<0.0001	<0.0001	<0.0001
Thallium	D-Tl	<0.0001	<0.0001	<0.0001	<0.0001
Uranium	D-U	0.00147	0.00156	0.00147	0.00142
Zinc	D-Zn	<0.005	<0.005	<0.005	<0.005

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

Outlines of the methodologies utilized for the analysis of the samples submitted are as follows:

Conventional Parameters in Water

These analyses are carried out in accordance with procedures described in "Methods for Chemical Analysis of Water and Wastes" (USEPA), "Manual for the Chemical Analysis of Water, Wastewaters, Sediments and Biological Tissues" (BCMOE), and/or "Standard Methods for the Examination of Water and Wastewater" (APHA). Further details are available on request.

Metals in Water

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" 19th Edition 1995 published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotplate or microwave oven, or filtration (EPA Method 3005A). Instrumental analysis is by atomic absorption/emission spectrophotometry (EPA Method 7000A), inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B), and/or inductively coupled plasma - mass spectrometry (EPA Method 6020).

Mercury in Water

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" 19th Edition 1995 published by the American Public Health Association. A cold-oxidation procedure involving bromine monochloride is used, followed by instrumental analysis by cold-vapour atomic absorption spectrophotometry (CVAAS).

End of Report

Appendix C-2:
ASL Chemical Analysis Report for Soil Samples

1988 Triumph Street, Vancouver, B.C., Canada V5L 1K5

analytical service laboratories ltd.

FAX: (604) 253-6700 TEL: (604) 253-4188

CHEMICAL ANALYSIS REPORT

Date: October 1, 1998

ASL File No. J8625

Report On: Yukon Sediment Analysis

Report To: **Royal Roads University**
Applied Research Division
2005 Sooke Road
Victoria, BC
V9B 5Y2

Attention: **Dr. Matthew Dodd**, Professor

Received: September 16, 1998

ASL ANALYTICAL SERVICE LABORATORIES LTD.
per:

Frederick Chen, B.Sc. - Manager, Special Projects
Brent A. Makelki, B.Sc. - Supervisor, Client Services

REMARKS

File No. J8625

Please note that the detection limits for several metals parameters have been increased due to matrix interferences caused by elevated chromium and nickel concentrations found in the samples.

RESULTS OF ANALYSIS - Sediment/Soil

File No. J8625

		CLMS-1S	CLMS-2S	CLMS-3S	CLMS-5S	CLMS-9S
		98 09 12 10:45	98 09 12 11:30	98 09 12 12:10	98 09 12 12:35	98 09 12 16:00
Physical Tests						
Moisture	%	43.4	27.0	9.8	15.5	15.4
pH		8.86	9.08	8.59	7.93	8.43
Total Metals						
Antimony	T-Sb	<100	<100	<100	<40	<80
Arsenic	T-As	74	14	3.2	160	265
Barium	T-Ba	981	207	279	502	228
Beryllium	T-Be	<3	<3	<3	<1	<2
Cadmium	T-Cd	<0.1	<0.1	<0.1	2.0	<0.1
Chromium	T-Cr	1410	1380	1650	771	928
Cobalt	T-Co	103	81	87	60	76
Copper	T-Cu	7	<5	<5	30	<4
Lead	T-Pb	<300	<300	<300	<100	<200
Mercury	T-Hg	0.109	0.018	0.018	0.172	0.409
Molybdenum	T-Mo	<20	<20	<20	<8	<20
Nickel	T-Ni	2210	2030	2140	1150	1740
Selenium	T-Se	<0.1	<0.1	<0.1	3.5	<0.1
Silver	T-Ag	<10	<10	<10	<4	<8
Tin	T-Sn	<50	<50	<50	<20	<40
Vanadium	T-V	26	21	11	34	<8
Zinc	T-Zn	30	13	14	133	6

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per dry kilogram except where noted.
< = Less than the detection limit indicated.

ASL

RESULTS OF ANALYSIS - Sediment/Soil

File No. J8625

		CLMS-10S	CLMS-11S	CLMS-12S	CLMS-13S	CLWC-1S
		98 09 12 16:05	98 09 12 16:50	98 09 12 17:20	98 09 12 18:30	98 09 12 16:05
Physical Tests						
Moisture	%	13.3	7.7	10.6	9.5	45.5
pH		8.52	9.55	8.56	7.02	6.46
Total Metals						
Antimony	T-Sb	<60	<40	<100	<20	<20
Arsenic	T-As	321	2.4	2.4	7	11
Barium	T-Ba	588	5	346	270	223
Beryllium	T-Be	<2	<1	<3	0.8	<0.5
Cadmium	T-Cd	<0.1	<0.1	<0.1	0.4	0.6
Chromium	T-Cr	1430	1530	1470	36	62
Cobalt	T-Co	99	65	111	19	11
Copper	T-Cu	3	<2	<5	42	26
Lead	T-Pb	<200	<100	<300	<50	<50
Mercury	T-Hg	0.444	<0.005	0.034	0.057	0.080
Molybdenum	T-Mo	<20	<8	<20	<4	5
Nickel	T-Ni	2200	1640	2300	54	70
Selenium	T-Se	<0.1	<0.1	0.1	1.1	1.6
Silver	T-Ag	<6	<4	<10	<2	<2
Tin	T-Sn	<30	<20	<50	<10	<10
Vanadium	T-V	19	8	20	43	30
Zinc	T-Zn	12	9	14	122	97

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per dry kilogram except where noted.
< = Less than the detection limit indicated.

ASL

RESULTS OF ANALYSIS - Sediment/Soil

File No. J8625

			CLWC-2S	CLWC-3S	CLMS-14	CLWR-3S	CLWR-4S
			98 09 12 19:15	98 09 12 19:20	98 09 10 10:40	98 09 13 12:00	98 09 13 12:05
Physical Tests							
Moisture	%		29.2	27.2	-	8.1	7.8
pH			8.53	8.37	-	7.92	8.03
Total Metals							
Antimony	T-Sb		<100	<100	-	<20	<20
Arsenic	T-As		11	9	-	13	14
Barium	T-Ba		41	49	-	84	103
Beryllium	T-Be		<3	<3	-	0.5	0.7
Cadmium	T-Cd		<0.1	<0.1	-	2.3	2.5
Chromium	T-Cr		1580	1670	-	19	22
Cobalt	T-Co		88	89	-	15	15
Copper	T-Cu		<5	5	-	58	62
Lead	T-Pb		<300	<300	-	<50	<50
Mercury	T-Hg		0.011	0.016	-	0.299	0.343
Molybdenum	T-Mo		<20	<20	-	14	16
Nickel	T-Ni		1920	1860	-	65	64
Selenium	T-Se		0.1	0.2	-	8	8
Silver	T-Ag		<10	<10	-	<2	<2
Tin	T-Sn		<50	<50	-	<10	<10
Vanadium	T-V		14	21	-	30	36
Zinc	T-Zn		19	25	-	248	238
Polychlorinated Biphenyls							
Total Polychlorinated Biphenyls			-	-	<0.05	-	-

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per dry kilogram except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Sediment/Soil File No. J8625

		CLWR-5S	CLWR-6S	CLWR-7S	CLWR-10S	CLWR-11S
		98 09 13 13:50	98 09 13 14:25	98 09 13 15:20	98 09 13 16:00	98 09 13 16:25
Physical Tests						
Moisture	%	18.7	17.6	29.7	6.6	16.5
pH		8.44	7.86	8.42	8.38	8.01
Total Metals						
Antimony	T-Sb	<80	<100	<100	<80	<20
Arsenic	T-As	28	13	17	15	18
Barium	T-Ba	65	397	1060	10	296
Beryllium	T-Be	<2	<3	<3	<2	0.8
Cadmium	T-Cd	0.2	<0.1	0.5	<0.1	1.6
Chromium	T-Cr	1110	1810	625	1180	486
Cobalt	T-Co	55	105	46	76	49
Copper	T-Cu	25	10	21	14	48
Lead	T-Pb	<200	<300	<300	<200	<50
Mercury	T-Hg	0.046	0.142	0.167	0.197	0.297
Molybdenum	T-Mo	<20	<20	<20	<20	12
Nickel	T-Ni	1230	852	867	1710	834
Selenium	T-Se	0.3	0.1	1.2	<0.1	4.4
Silver	T-Ag	<8	<10	<10	<8	<2
Tin	T-Sn	<40	<50	<50	<40	<10
Vanadium	T-V	23	66	47	<8	38
Zinc	T-Zn	29	27	71	8	143

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per dry kilogram except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Sediment/Soil

File No. J8625

		CBLK-1S	CBLK-2S	CBLK-3S
		98 09 13 17:30	98 09 13 18:20	98 09 13 18:30
Physical Tests				
Moisture	%	5.6	10.7	8.6
pH		8.69	8.90	7.64
Total Metals				
Antimony	T-Sb	<200	<20	<100
Arsenic	T-As	167	15	20
Barium	T-Ba	3160	893	76
Beryllium	T-Be	<4	0.8	<3
Cadmium	T-Cd	<0.1	2.4	<0.1
Chromium	T-Cr	3010	132	1420
Cobalt	T-Co	134	12	70
Copper	T-Cu	20	39	7
Lead	T-Pb	<400	<50	<300
Mercury	T-Hg	0.078	0.162	0.051
Molybdenum	T-Mo	<30	6	<20
Nickel	T-Ni	2560	183	1760
Selenium	T-Se	0.2	9	<0.1
Silver	T-Ag	<20	<2	<10
Tin	T-Sn	<70	<10	<50
Vanadium	T-V	51	40	13
Zinc	T-Zn	37	103	16

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per dry kilogram except where noted.
< = Less than the detection limit indicated.

Outlines of the methodologies utilized for the analysis of the samples submitted are as follows:

Moisture

This analysis is carried out gravimetrically by drying the sample at 103 C for a minimum of three hours.

pH in Soil

This analysis is carried out in accordance with procedures described in "Soil Sampling and Methods of Analysis" (CSSS). The procedure involves mixing the air-dried sample with deionized/distilled water. The pH of the solution is then measured using a standard pH probe. A one to two ratio of sediment to water is used for mineral soils and a one to ten ratio is used for highly organic soils.

Metals in Sediment/Soil

This analysis is carried out using procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 Method 3050B or Method 3051, published by the United States Environmental Protection Agency (EPA). The sample is manually homogenized and a representative subsample of the wet material is weighed. The sample is then digested by either hotplate or microwave oven using a 1:1 ratio of nitric acid and hydrochloric acid. Instrumental analysis is by atomic absorption spectrophotometry (EPA Method 7000A) and/or inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

Method Limitation: This method is not a total digestion technique for most samples. It is a very strong acid digestion that will dissolve almost all elements that could become "environmentally available." By design, elements bound in silicate structures are not normally dissolved by this procedure as they are not usually mobile in the environment.

Polychlorinated Biphenyls in Sediment

This analysis is carried out using a procedure adapted from EPA Method 8082 (Publ. # SW-846 3rd ed., Washington, DC 20460). The procedure involves a solid-liquid extraction of the sample with hexane/acetone and back extraction with water. The hexane extract is cleaned and analysed by capillary column gas chromatography with electron capture detection.

End of Report

CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM

1988 Triumph Street
Vancouver, BC
Canada V5L 1K5
FAX: (604) 253-6700
TEL: (604) 253-4188
TOLL FREE: (800) 665-0243

Specialists in Environmental Chemistry

analytical service laboratories ltd.

ANALYSIS REQUESTED PAGE ____ OF ____

CLIENT: ROYAL ROADS UNIV
ADDRESS: 2005 SOOKE RD
CONTACT: MATT DODD
TELEPHONE: (250) 391-2583 FAX: (250) 391-2560
PROJECT NAME/NO.:
QUOTE / P.O. NO.:
DATE SUBMITTED: Sept 15 98 ASL CONTACT: BRENT MIHKELZKI

LAB USE ONLY: 38625

FOR LAB USE ONLY	SAMPLE IDENTIFICATION	Y	M	D	TIME COLLECTED	MATRIX	METALS	NOTES
1	CLMS-1S	98	09	12	10:45 AM	Sediment	X	
2	CLMS-2S	✓	✓	✓	11:30 AM	Soil	X	
3	CLMS-3S	✓	✓	✓	12:10 PM	✓	X	
	CLMS-4S	✓	✓	✓	12:20 PM	✓		
4	CLMS-5S	✓	✓	✓	12:35 PM	✓	X	
	CLMS-6S	✓	✓	✓	1:30 PM	✓		
	CLMS-7S	✓	✓	✓	1:50 PM	✓		
	CLMS-8S	✓	✓	✓	3:30 PM	✓		
5	CLMS-9S	✓	✓	✓	[illegible]:00 PM	✓	X	
6	CLMS-10S	✓	✓	✓	4:05 PM	✓	X	
7	CLMS-11S	✓	✓	✓	4:50 PM	✓	X	
8	CLMS-12S	✓	✓	✓	5:20 PM	✓	X	
9	CLMS-13S	✓	✓	✓	6:30 PM	✓	X	
10	CLWC-1S	✓	✓	✓	6:05 PM	Sediment	X	
11	CLWC-2S	✓	✓	✓	7:15 PM	✓	X	
12.	CLWC-3S	✓	✓	✓	7:20 PM	✓	X	

TURN AROUND REQUIRED:
- [X] ROUTINE (7 - 10 WORKING DAYS)
- [ ] RUSH (SPECIFY DATE):

SPECIAL INSTRUCTIONS:

SAMPLE CONDITION UPON RECEIPT:
- [ ] FROZEN
- [ ] COLD
- [ ] AMBIENT

RELINQUISHED BY:	DATE / TIME	RECEIVED BY:	DATE / TIME
MDodd	DATE Sept 15, 98 TIME 9:02 am		DATE TIME
	DATE TIME		DATE TIME

CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM

1988 Triumph Street
Vancouver, BC
Canada V5L 1K5
FAX: (604) 253-6700
TEL: (604) 253-4188
TOLL FREE: (800) 665-0243

Specialists in
Environmental Chemistry

analytical service
laboratories ltd.

ANALYSIS REQUESTED PAGE ____ OF ____ 5

CLIENT: ROYAL ROADS
ADDRESS: 2005 SOOKE RD
CONTACT:
TELEPHONE: 391-2583 FAX: 391-2580
PROJECT NAME/NO.:
QUOTE / P.O. NO.:
DATE SUBMITTED: ASL CONTACT:

LAB USE ONLY: 58625

	FOR LAB USE ONLY	SAMPLE IDENTIFICATION	Y	M	D	TIME	AM/PM	MATRIX	METALS	PCBS	NOTES
		CLWC-4S	98	09	12	7:45	PM	SEDIMENT			
		CLWC-5S	98	09	13	6:05	PM	✓			
1	13	CLMS-14	98	09	10	10:40	AM	SOIL		X	
2		CLWR-1S	98	09	13	10:40	AM	Sediment			
3		CLWR-2S	✓	✓	✓	11:15	AM	SOIL			
	14	CLWR-3S	✓	✓	✓	12:00	PM	✓	X		
4	15	CLWR-4S	✓	✓	✓	12:05	PM	✓	X		
	16	CLWR-5S	✓	✓	✓	1:50	PM	✓	X		
	17	CLWR-6S	✓	✓	✓	2:25	PM	✓	X		
	18.	CLWR-7S	✓	✓	✓	3:20	AM	✓	X		
5		CLWR-8S	✓	✓	✓	3:40	PM	✓			
6		CLWR-9S	✓	✓	✓	3:42	PM	✓			
7	19	CLWR-10S	✓	✓	✓	4:00	PM	✓	X		
8	20	CLWR-11S	✓	✓	✓	4:25	PM	✓	X		
9		CLWR-12	✓	✓	✓	5:00	PM	✓			
10		CLWR-14	✓	✓	✓	5:30	PM	✓			
11											
12											

TURN AROUND REQUIRED:
☐ ROUTINE (7 - 10 WORKING DAYS)
☐ RUSH (SPECIFY DATE):
SPECIAL INSTRUCTIONS:

SAMPLE CONDITION UPON RECEIPT:
☐ FROZEN
☐ COLD
☐ AMBIENT

RELINQUISHED BY:	DATE / TIME	RECEIVED BY:	DATE / TIME
[signature]	DATE Sept 15, 98 TIME [illegible]		DATE TIME
	DATE TIME		DATE TIME

CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM

CLIENT: ROYAL ROADS UNIV
ADDRESS: 2005 SOOKE RD
CONTACT: MATT DODD
TELEPHONE: 391-2583 FAX: 391-2580
PROJECT NAME/NO.:
QUOTE / P.O. NO.:
DATE SUBMITTED: Sept 15, 98 ASL CONTACT: Brent makelka

1988 Triumph Street
Vancouver, BC
Canada V5L 1K5
FAX: (604) 253-6700
TEL: (604) 253-4188
TOLL FREE: (800) 665-0243

Specialists in Environmental Chemistry

analytical service laboratories ltd.

ANALYSIS REQUESTED

LAB USE ONLY	SAMPLE IDENTIFICATION	Y	M	D	TIME	MATRIX	METALS												NOTES
21	CLBK - 1S	98	09	13	5 : 30 PM	SOIL	X												
22	CLBK - 2S	98	09	13	6 : 20 PM	✓	X												
23	CLBK - 3S	98	09	13	6 : 30 PM	✓	X												
					: AM/PM														
14					: AM/PM														
15					: AM/PM														
16					: AM/PM														
17					: AM/PM														
18					: AM/PM														
					: AM/PM														
					: AM/PM														
19					: AM/PM														
20					: AM/PM														
					: AM/PM														
					: AM/PM														
					: AM/PM														

FOR LAB USE ONLY

TURN AROUND REQUIRED:
- ☐ ROUTINE (7 - 10 WORKING DAYS)
- ☐ RUSH (SPECIFY DATE):

SPECIAL INSTRUCTIONS:

SAMPLE CONDITION UPON RECEIPT:
- ☐ FROZEN
- ☐ COLD
- ☐ AMBIENT

RELINQUISHED BY:	DATE / TIME	RECEIVED BY:	DATE / TIME
[illegible signature]	DATE: 15 Sept 98 TIME: 9.00 am		DATE: TIME:
RELINQUISHED BY:	DATE: TIME:	RECEIVED BY:	DATE: TIME:

Appendix C-3:
North West Environmental Group Analysis Report for Asbestos in Soil & Sediment Samples

North
West
Environmental
Group Ltd.

#3 – 835 Devonshire Road
Victoria, B.C.
V9A 4T5

Tel: 250 384 9695
Fax: 250 384 9865
e-mail: nwest@pinc.com

October 15, 1998

Royal Roads University
2005 Sooke Road
Victoria, B.C.
V9B 5Y2

Attention: Mr. Matt Dodd

Dear Sir:

We have completed analysis of bulk samples submitted and report as follows.

A total of 30 soil samples were submitted for asbestos analysis. Analysis was carried out in accordance with procedures defined by the Workers' Compensation Board and the McCrone Research Institute.

Asbestos concentrations are reported as percent of the total sample. Procedures allow for variation of +/- 10% in reporting results. However, the non-homogeneous nature of these samples suggests that a variation greater than 10% should be used.

Samples where asbestos was not identified were analyzed in duplicate to ensure accuracy of results.

I hope this information is helpful to you and I look forward to working with you in the future.

Yours truly,

Robert Christie, B.Sc., MBA, CIH
Principal

1012-R1

North West Environmental
Project Number: 1012
Royal Roads University - Bulk Sample Results

15/10/98

NO.	DATE	SAMPLE INFORMATION	DESCRIPTION	ASBESTOS		OTHER	ANALYST
1	07/10/98	CLMS-13 Sediment	1 sediment (100%)	None Detected		cellulose(3%), nf(97%)	RC
2	07/10/98	CLWC-1 Sediment	1 sediment (100%)	None Detected		cellulose(25%), nf(75%)	RC
3	07/10/98	CLWC-2 Sediment	1 sediment (100%)	Chrysotile	10%	nf(90%)	RC
4	07/10/98	CLWC-3 sediment	1 Sediment (100%)	Chrysotile	3-5%	cellulose(2%), nf(93%)	RC
5	07/10/98	CLWR-3 sediment	1 Sediment (100%)	Chrysotile	1-2%	cellulose(2%), nf(97%)	RC
6	07/10/98	CLWR-4 sediment	1 Sediment (100%)	Chrysotile	< 1%	cellulose(1%), nf(99%)	RC

NF = Non-Fibrous material; SS = Small Sample size
PLEASE NOTE: Due to space limitations, these sample(s) will be disposed of after 3 months, unless we are instructed otherwise by our client.

North West Environmental
Project Number: 1012
Royal Roads University - Bulk Sample Results

15/10/98

NO.	DATE	SAMPLE INFORMATION	DESCRIPTION	ASBESTOS		OTHER	ANALYST
7	07/10/98	CLWR-1 sediment	1 Sediment (100%)	Chrysotile	3-5%	cellulose(1%), nf(95%)	RC
8	07/10/98	CLWR-11 sediment	1 Sediment (100%)	Chrysotile	7%	cellulose(1%), nf(92%)	RC
9	07/10/98	CLWR-15 sediment	1 Sediment (100%)	Chrysotile	6%	cellulose(1%), nf(93%)	RC
10	07/10/98	CLBK-1 sediment	1 Sediment (100%)	Chrysotile	3-5%	cellulose(2%), nf(95%)	RC
11	08/10/98	CLCR-27 Sediement	1 sediment (100%)	None Detected		cellulose(4%), nf(96%)	RC
12	08/10/98	CLCR-28 Sediment	1 sediment (100%)	None Detected		cellulose(10%), nf(90%)	RC

NF = Non-Fibrous material; SS = Small Sample size
PLEASE NOTE: Due to space limitations, these sample(s) will be disposed of after 3 months, unless we are instructed otherwise by our client.

NO.	DATE	SAMPLE INFORMATION		DESCRIPTION	ASBESTOS		OTHER	ANALYST
13	08/10/98	CLCR-29 Sediment	1	sediment (100%)	None Detected		cellulose(2%), nf(98%)	RC
14	08/10/98	CLMS-1 Sediment	1	sediment (100%)	Chrysotile	35%	nf(65%)	RC
15	08/10/98	CLMS-2 Sediment	1	sediment (100%)	Chrysotile	40%	nf(60%)	RC
16	09/10/98	CLMS-3 Sediment	1	sediment (100%)	Chrysotile	15%	nf(85%)	RC
17	09/10/98	CLMS-4 Sediment	1	sediment (100%)	Chrysotile	15%	nf(85%)	RC
18	09/10/98	CLMS-6 Sediment	1	sediment (100%)	Chrysotile	10%	cellulose(2%), nf(88%)	RC

NF = Non-Fibrous material; SS = Small Sample size
PLEASE NOTE: Due to space limitations, these sample(s) will be disposed of after 3 months, unless we are instructed otherwise by our client.

NO.	DATE	SAMPLE INFORMATION		DESCRIPTION	ASBESTOS		OTHER	ANALYST
19	09/10/98	CLMS-9 Sediment	1	sediment (100%)	Chrysotile	40%	nf(60%)	RC
20	09/10/98	CLMS-10 Sediment	1	sediment (100%)	Chrysotile		nf(70%)	RC
21	09/10/98	CLCR-2 Sediment	1	sediment (100%)	Chrysotile	3-5%	cellulose(1%), nf(94%)	RC
22	09/10/98	CLCR-3 Sediment	1	sediment (100%)	Chrysotile	3-5%	nf(97%)	RC
23	09/10/98	CLCR-4 Sediment	1	sediment (100%)	Chrysotile	1-2%	cellulose(1%), nf(98%)	RC
24	09/10/98	CLCR-5 Sediment	1	sediment (100%)	Chrysotile	1-2%	cellulose(3%), nf(96%)	RC

NF = Non-Fibrous material; SS = Small Sample size
PLEASE NOTE: Due to space limitations, these sample(s) will be disposed of after 3 months, unless we are instructed otherwise by our client.

NO.	DATE	SAMPLE INFORMATION	DESCRIPTION	ASBESTOS		OTHER	ANALYST
25	09/10/98	CLCR-7 Sediment	1 sediment (100%)	None Detected		cellulose(1%), nf(99%)	RC
26	09/10/98	CLCR-23 Sediment	1 sediment (100%)	None Detected		cellulose(1%), nf(99%)	RC
27	09/10/98	CLCR-23B Sediment	1 sediment (100%)	None Detected		cellulose(1%), nf(99%)	RC
28	09/10/98	CLCR-24 Sediment	1 sediment (100%)	Chrysotile	1-2%	nf(98%)	RC
29	09/10/98	CLCR-25 Sediment	1 sediment (100%)	Chrysotile	< 1%	nf(99%)	RC
30	09/10/98	CLCR-26 Sediment	1 sediment (100%)	Chrysotile	< 1%	nf(99%)	RC

NF = Non-Fibrous material; SS = Small Sample size
PLEASE NOTE: Due to space limitations, these sample(s) will be disposed of after 3 months, unless we are instructed otherwise by our client.

Appendix C-4:
EMSL Laboratory Analysis Report for Asbestos in Water

Westmont, NJ (609) 858-1260 | Piscataway, NJ (908) 981-0550 | Carle Place, NY (516) 997-7251 | Smyrna, GA (404) 333-6066 | Melbourne, FL (407) 253-4224 | Ann Arbor, MI (313) 668-6810 | San Mateo, CA (415) 570-5401

EMSL

Thursday, October 1, 1998

Royal Roads University
2005 Sooke Road
Victoria, BC V9B 5Y2

Project: Canada
Attention: Matt Dodd
Ref Number: CA986778
Date Sampled 9-10-98 - 9-12-98

Asbestos Analysis in Water by Transmission Electron Microscopy (TEM) Performed by Method EPA/600/R-94/134 - (100.2)
"Determination of Asbestos Structures Over 10µm In Length in Drinking Water"; by Brackett, Clark & Millette

SAMPLE ID	#ASBESTOS STRUCTURES		#NON-ASBESTOS FIBROUS STRUCTURES	TYPE(S) OF ASBESTOS	CONCENTRATION OF ASBESTOS STRUCTURES (MILLIONS/LITER)		95% Confidence Limits (Lower-Upper) (MILLIONS/LITERS)		DETECTION LIMIT (MFL)
	>10µm	≤10µm			>10µm	Total	>10 µm	Total	
CLCR-Z3B	0	4	0	Chysotile	<1.07	4.29	0.02-5.98	1.17-10.99	1.07
CLCR-Z8	0	1	1	Chysotile	<1.07	1.07	0.02-5.98	0.02-5.98	1.07
CLCR-2 wc	0	22	0	Chysotile	<1.07	22.62	0.02-5.98	14.8-35.76	1.07
CLCR-3 wc	0	9	0	Chysotile	<1.07	9.66	0.02-5.98	4.43-18.34	1.07
CLCR-5	0	8	1	Chysotile	<1.07	8.59	0.02-5.98	3.71-16.92	1.07
CLCR-7	0	5	0	Chysotile	<1.07	5.36	0.02-5.98	1.74-12.51	1.07
CLCR-8	0	0	2	Chysotile	<1.07	<1.07	0.02-5.98	0.02-5.98	1.07
CLCR-Z6	14	128	5	Chysotile	15.03	152.45	8.2-25.22	119.9-191.52	1.07
CLCR-6	0	10	9	Chysotile	<1.07	10.73	0.02-5.98	5.15-19.74	1.07
CLCR-2	2	103	1	Chysotile	2.15	112.73	0.03-7.75	89.13-143.06	1.07
CLCR-6A	1	12	2	Chysotile	1.07	13.96	0.02-5.98	7.43-23.87	1.07
EMSL Blank	0	0	0	None Detected	<0.18	<0.18	0-0.68	0-0.68	0.18

***Samples that contain high levels of particulate which require the laboratory to filter a dilution less than the minimum recommended method volume of 50 ml, will necessarily have higher detection limits. Refer to EPA/600/R-94/134 Method 100.2, Sections 11.10 and 13.6.**

Analyst

Approved Signatory

ACCREDITATIONS: NVLAP #101048-03 and CA STATE ELAP #1620

ROYAL ROADS UNIVERSITY

2005 Sooke Road
Victoria, BC, V9B 5Y2

CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM

Project Name/No:

RRU Contact: Matt Dodd
Phone/Fax #: (250) 391-2583 / 391-2560
E-mail: matt.dodd@royalroads.ca

Laboratory: EMSL Analytical
Lab Contact: Carol Evans
Phone/~~Fax~~ #: (206) 233-9007

Sample #	Date	Time	Sample Type	Preservative	Analysis Requested: Asbestos						Remarks/Notes
CLCR-23B	Sept 11 '98	3:50 pm	water	formalin	✓						
CLCR-28	Sept 11 98	7:45 pm	✓	✓	✓						
CLWC-2	Sept 12, 98	6:15 pm	✓	✓	✓						
CLWC-3	Sept 12, 98	6:20 pm	✓	✓	✓						
CLCR-5	Sept 10, 98	4:10 pm	✓	✓	✓						
CLCR-7	Sept 10, 98	5:15 pm	✓	✓	✓						
CLCR-8	Sept 10, 98	5:30 pm	✓	✓	✓						
CLCR-26	Sept 11, 98	2:00 pm	✓	✓	✓						
CLCR-6	Sept 10, 98	5:05 pm	✓	✓	✓						
CLCR-2	Sept 10, 98	11:00 am	✓	✓	✓						
CLCR-6A	Sept 11, 98	11:00 am	✓	✓	✓						

Relinquished By:	Date / Time	Received By:	Date / Time	Special Instructions:
[signature]	Date: Sept 18, 98 Time: 3:00 pm	[signature]	Date: Sept 22, 1998 Time: 9:10 AM	
Relinquished By:	Date: Time:	Received By: [signature] EMSL	Date: 9/30/98 Time: 12:35 pm	

Appendix D: Quality Assurance/Quality Control (QA/QC)

D. QUALITY ASSURANCE/QUALITY CONTROL

D.1 Field QA/QC

The field QA/QC program incorporated measures, which ensured the integrity of the soil, sediment, biota and water samples collected and met the sampling program data quality objectives. Aspects of the program are described in the following sections.

D.1.1 Sampling Protocols

In order to guarantee that all the samples collected maintained their integrity prior to analysis, the general protocols presented in Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites (CCME, 1993) were used. Briefly, each soil/sediment sample was collected with a dedicated pre-cleaned stainless steel scoop while water samples were collected directly into containers. All the samples were placed in appropriate pre-cleaned containers supplied by the analytical laboratories. The containers were labeled, placed in coolers and transported via Canadian Air cargo to the laboratory for analysis. Sample information was recorded on the chain-of-custody forms, copies of which accompanied the shipment.

D.1.2 Documentation

All events were documented in field notebooks. Records included date, time, site identification, site conditions, sample type, preservatives, visual characteristics, odour, chain of custody, and photographs.

D.1.3 Field Quality Control Samples

In addition to the samples collected to meet the objective of the overall program, field duplicate samples were taken to meet a QA/QC objective of monitoring precision/reproducibility of sampling activities. At least one field duplicate of soil or sediment sample was collected from each area of the site. A summary of the samples collected is given in Table D-1.

Table D-1: Summary of Field Duplicate Samples Collected for Soil/Sediments

Area of Site	No. of Field Duplicates	Sample Designation
Hudgeon Lake	1	CLCR-1 and CLCR-9
Wolverine Creek	1	CLWC-2 and CLWC-3
Mill Site/Tailings	1	CLMS-9 and CLMS-10
Waste Rock	2	CLWR-3 and CLWR-4
		CLWR-11 and CLWR-15

For water analysis, one field duplicate was collected for each analyte group as presented in Table D-2 below.

Table D-2: Summary of Field Duplicate Samples Collected for Water

Parameter	Sample Designation
Total Metals	CLCR-1 & CLCR-9
Dissolved Metals	CLCR-1 & CLCR-9
Anions and Nutrients	CLWC-2 & CLWC-3
Asbestos	CLWC-2 & CLWC-3

D.2 Laboratory QA/QC

Soil, sediment and water samples were submitted to Analytical Services Laboratory (ASL), Vancouver for metal, anions and nutrients analysis. Asbestos analysis for soil/sediment samples was performed at North West Environmental while that for water was carried out at EMSL Analytical, San Mateo, California.

ASL has been evaluated and accredited by the Canadian Association for Environmental Laboratories while EMSL has accreditation with the United States Department of Commerce, National Institute of Standards and Technology, National Voluntary Laboratory Accreditation Program (NVLAP) and the California State Environmental Laboratory Accreditation Program (ELAP). North West Environmental employed methodology approved by the Workers Compensation Board.

Prior to and throughout the field program, the laboratory was contacted to ensure that all QA/QC objectives; such as detection limits, proper sample containers, and sample delivery; were being met.

The QA/QC program, set up to monitor data quality and reliability on an ongoing basis by ASL, included running all samples in batches of varying sizes with control samples, which accompanied the set through the entire analytical procedure. These control samples included the following:

- analytical or procedural duplicates to monitor precision or reproducibility of the results; and
- procedural blanks to monitor interferences from potential laboratory contamination.

The QA/QC program set up externally by Royal Roads to monitor data quality and reliability included analyzing one field duplicate for each parameter. The data obtained is discussed in the next sections.

D.3 Evaluation of Field Quality Control Data

The field duplicate samples were submitted to the laboratory for analysis as individual samples. The data obtained was evaluated by direct comparison or by calculating the relative standard deviation (RSD), which is simply the standard deviation of the duplicates divided by the mean (expressed as a percentage). Values of RSD less than 30% indicate reasonable to good precision, while those exceeding this value are considered fair to poor.

D.3.1 Anions and Nutrients in Water

Reproducibility for the analysis for total alkalinity, bromide, chloride, fluoride, sulphate, nitrate and nitrite was monitored with one pair of a field duplicate sample. The concentrations of most bromide, nitrate and nitrite were below detection (Table D-3). The relative standard deviations for the remaining analytes were between 0.0 and 1.6% indicating good precision.

Table D-3: Anions and Nutrients Concentrations for Field Duplicate Water Samples

Parameter	CLWC-2	CLWC-3	Relative Standard Deviation (%)
	Concentration (mg/L)		
Anions			
Alkalinity-Total as $CaCO_3$	88	86	1.6
Bromide	<0.5	<0.5	-
Chloride	0.6	0.6	0.0
Fluoride	0.14	0.14	0.0
Sulphate	128	127	0.6
Nutrients			
Nitrate - Nitrogen	<0.1	<0.1	-
Nitrite - Nitrogen	<0.1	<0.1	-

D.3.2 Metals in Water

One pair each of a field duplicate sample was used to monitor total metal and dissolved metal analysis. Good precision was obtained for all of the detectable analytes based on the RSD values (Table D-4). The RSD values ranged from 0.0 to 9.0%. Thus good reproducibility was obtained for metal in water analysis.

Table D-4: Total and Dissolved Metal Concentrations and Relative Standard Deviations (RSD) for Duplicate Water Samples

Parameter	Total Metal (mg/L)		RSD (%)	Dissolved Metal (mg/L)		RSD (%)
	CLCR-1	CLCR-9		CLCR-1	CLCR-9	
Aluminum	0.059	0.059	0.0	0.103	0.092	8.0
Antimony	<0.2	<0.2	-	<0.2	<0.2	-
Arsenic	<0.2	<0.2	-	<0.2	<0.2	-
Barium	0.05	0.05	0.0	0.05	0.05	0.0
Beryllium	<0.005	<0.005	-	<0.005	<0.005	-
Boron	<0.1	<0.1	-	<0.1	<0.1	-
Cadmium	<0.0002	<0.0002	-	<0.0002	<0.0002	-
Calcium	46.8	44.9	2.9	45.2	46.1	1.4
Chromium	<0.01	<0.01	-	<0.01	<0.01	-
Cobalt	<0.01	<0.01	-	<0.01	<0.01	-
Copper	0.02	<0.01	-	<0.01	<0.01	-
Iron	0.23	0.21	6.4	0.25	0.22	9.0
Lead	<0.001	<0.001	-	<0.001	<0.001	-
Magnesium	26	25.7	0.8	26.2	26.4	0.5
Manganese	0.11	0.111	0.6	0.11	0.111	0.6
Mercury	<0.00005	<0.00005	-	<0.00005	<0.00005	-
Molybdenum	<0.03	<0.03	-	<0.03	<0.03	-
Nickel	<0.05	<0.05	-	<0.05	<0.05	-
Selenium	0.0014	0.0013	5.2	0.0012	0.0011	6.1
Silver	<0.0001	<0.0001	-	<0.0001	<0.0001	-
Thallium	<0.0001	<0.0001	-	<0.0001	<0.0001	-
Uranium	0.00141	0.00141	0.0	0.00147	0.00147	0.0
Zinc	<0.005	<0.005	-	<0.005	<0.005	-

D.3.3 Metals in Soil

In order to monitor the reproducibility for metals in soil/sediment analysis, two sets of field duplicate samples were analyzed (Table D-5). Good to fair precision was indicated for samples CLWC-2 and CLWC-3 based on the RSD values found 0.8 to 30%). The RSD for barium (62%) and zinc (47%) in CLMS-9 and CLMS-10 however, indicated poor reproducibility for these two metals. The poor reproducibility for this sample may be attributed to sample heterogeneity since the substrate consisted of coarse sand mixed with small rocks, stones and tailings.

Table D-5: Metal Concentrations and Relative Standard Deviations (RSD) for Duplicate Water Samples

Parameter	Concentration (mg/kg)		RSD (%)	Concentration (mg/kg)		RSD (%)
	CLMS-9	CLMS-10		CLWC-2	CLWC-3	
Antimony	<80	<60	-	<100	<100	-
Arsenic	265	321	13	11	9	14
Barium	228	588	62	41	49	12
Beryllium	<2	<2	-	<3	<3	-
Cadmium	<0.1	<0.1	-	<0.1	<0.1	-
Chromium	928	1430	30	1580	1670	3.9
Cobalt	76	99	19	88	89	0.8
Copper	<4	3	-	<5	5	-
Lead	<200	<200	-	<300	<300	-
Mercury	0.409	0.444	5.8	0.011	0.016	26
Molybdenum	<20	<20	-	<20	<20	-
Nickel	1740	2200	16	1920	1860	2.2
Selenium	<0.1	<0.1	-	0.1	0.2	47
Silver	<8	<6	-	<10	<10	-
Tin	<40	<30	-	<50	<50	-
Vanadium	<8	19	-	14	21	28
Zinc	6	12	47	19	25	19

D.3.4 Asbestos in Soil/Sediment

Asbestos analysis was carried out in accordance with procedures defined by the Workers Compensation Board and the McCrone Research Institute. The procedures allow for a variation of ±10% in reporting results. A direct comparison of the data obtained for the duplicate samples (Table D-6) indicate the results are within acceptable limits.

Table D-6: Asbestos Concentrations and Relative Standard Deviations (RSD) for Duplicate Soil/Sediment Samples

Field Duplicate Sample Number	Asbestos Concentration (%)	RSD (%)
CLMS-9	40	20
CLMS-10	30	
CLWC-2	10	-
CLWC-3	3-5	
CLWR-11	7	11
CLWR-15	6	

D.3.5 Asbestos in Water

The concentration of asbestos in one set of a field duplicate sample analyzed is given in Table D-7. The data indicated poor reproducibility.

Table D-7: Metal Concentrations and 95% Confidence Limit for Duplicate Water Sample

Sample Number	Asbestos in Water (10^6 Fibres /Litre	
	Total	95% Confidence Limit
CLWC-2	22.62	14.8 – 35.76
CLWC-3	9.66	4.43 – 18.34