

**Government of Yukon
Former Clinton Creek
Asbestos Mine
Overview Report**

Prepared by:

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Project Number:

6029 013 00 (4.6.1)

Date:

July, 2009

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July 29, 2009

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Dear Rachel:

Re: Former Clinton Creek Asbestos Mine – Overview Report

AECOM Canada Ltd. is pleased to submit our final report on the above referenced project.

If we can be of further assistance, please contact Ken Skafffeld, P.Eng. or Gil Robinson, P.Eng. directly.

Sincerely,

AECOM Canada Ltd.



Ron Typliski, P.Eng.
Vice-President, Manitoba District
Canada West Region
GR/dh

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Signature Page

Report Prepared By:



Ken Skafffeld, P.Eng.



PERMIT TO PRACTICE	
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Date	July 27/09
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1. Introduction

1.1 Terms of Reference

This report provides a comprehensive overview of the physical condition of the former Clinton Creek Asbestos Mine, existing and past issues with respect to physical and environmental liabilities and work completed to date to address these liabilities. The report is largely based on a review of historical reports prepared during active mining operations, reports by AECOM (formerly UMA Engineering) and others subsequent to mine decommissioning and work completed by AECOM and others to assess and mitigate identified environmental and physical hazards. Information gaps associated with our current understanding of the physical stability of mine site elements and the associated stabilization options e.g. waste rock dump have also been identified.

The terms of reference for this report are outlined in our letter proposal to Ms. Rachel Pugh of the Government of Yukon (GY), Energy, Mines and Resources dated February 20, 2009. Work has been carried out under AECOM's Standing Offer AMB-07-001 for Engineering and Consulting Services related to Operating and Abandoned Mines in the Yukon.

1.2 Sources of Information and Participants

AECOM's work at the mine site dates back to 1998 when at the request of Indian and Northern Affairs Canada (INAC), an initial site reconnaissance was made by UMA Engineering (now operating as AECOM) to report on the condition of the mine. At the time of the site reconnaissance, relevant information from INAC's Library in Whitehorse related to the mine site was reviewed. Beginning in 1998, UMA Engineering provided engineering services for a number of projects at the mine, working for INAC until 2003 and subsequently with the Government of Yukon (as UMA Engineering and since September 2008 as AECOM). During that time, considerable background information has been gathered. While we have endeavoured to obtain all relevant information for the purposes of preparing this summary report, it is likely that there are sources of information that we are not aware of given the lengthy history associated with the site.

1.2.1 Sources of Information

Information for this report has been gathered from a number of sources and in collaboration with a number of participants. A list of references used for this report is attached at the end of this report. Separate lists have been provided for reports prepared by UMA Engineering and those prepared by others. Several of these reports are referenced within the text of the report. The majority of the reports have been prepared by Consultants either working for the former mine owners (Cassiar Asbestos Corp. Ltd.) or for INAC or the Government of Yukon. Additional information has been obtained from INAC and Fisheries and Oceans Canada.

2. Site Description

2.1 Location and Physical Environment

The former Clinton Creek Asbestos Mine is located about 100 km northwest of Dawson City, Yukon, and 19 km from the Alaska border as shown on Figure 01. The mine site is situated within a triangle bounded by the Yukon River, the Forty Mile River and the International (Yukon-Alaska) border at approximately UTM coordinates 7 147 500 N, 613 000 E. Access to the mine is from the Top of the World Highway connecting Dawson City and the Poker Creek border crossing in Alaska. The mine is situated along Clinton Creek about 9 km upstream of the confluence with the Forty Mile River. The Yukon River is about 5 km downstream on the Forty Mile River from the mouth of Clinton Creek. The former Clinton Creek Town Site, built to support the mine, is located on the west side of the bridge crossing at the Fort Mile River.

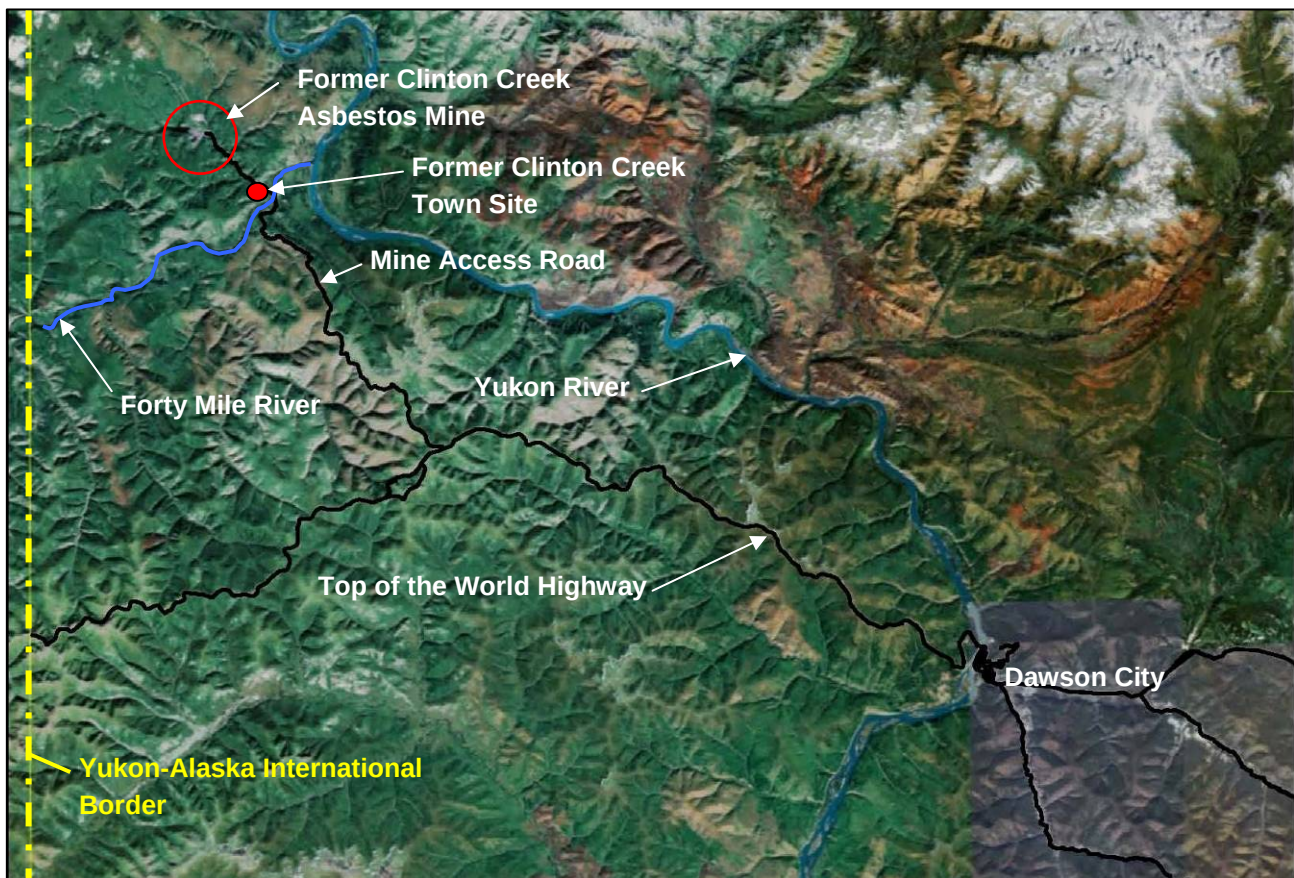


Figure 01 Key Plan (Source – Google Maps)

The former mine is located between approximately elevations 400 m above sea level (ASL) at the Clinton Creek valley floor and 590 m ASL at the former mill site. Local relief in the area is in the order of 245 m (Golder, 1978). The site is within the unglaciated Yukon-Tanana Upland in widespread discontinuous permafrost distribution. The maximum permafrost depth in the area is estimated to be in the order of 60 m

(EBA, 2004, Golder 1978). The presence of permafrost is evidenced by reports of segregated ice, in the form of large crystals and thick lenses being encountered in alluvial valley deposits and near surface bedrock in undisturbed ground (Stepanek and McAlpine, 1992).

Records kept during active mining (1968-1978) indicate an annual mean temperature of approximately -2.5 degrees C with average maximum and minimum temperatures of +15 degrees C (July) and -32 degrees C in January (Golder, 1978). Over the same period, the average annual precipitation was 360 mm/yr with minimum and maximum annual precipitation rated of 260 mm (1973) and 430 mm (1975).

2.2 Mine Site Layout

The mine layout is shown on Figure 02. It consists of three open pits; the Porcupine, Snowshoe and Creek Pits. The Porcupine and Snowshoe Pits are located along the top of a hillside on the south side of Clinton Creek. The Creek pit is located along the original alignment of Porcupine Creek. A crusher building was located on the high ground between the Porcupine and Creek Pits. The mill site is located on a plateau along the west side of the Wolverine Creek valley about 150 m higher than the mine site area. Ore was transported from the crusher to the mill site by way of an overhead tram line. Waste rock from the three open pits was deposited along the valley slopes immediately adjacent to the pits. The Porcupine and Clinton Creek waste rock dumps are the largest of the dumps. Tailings from the milling operation were deposited onto the Wolverine Creek valley slope. An airstrip is located about 1.5 km north of the mill site.

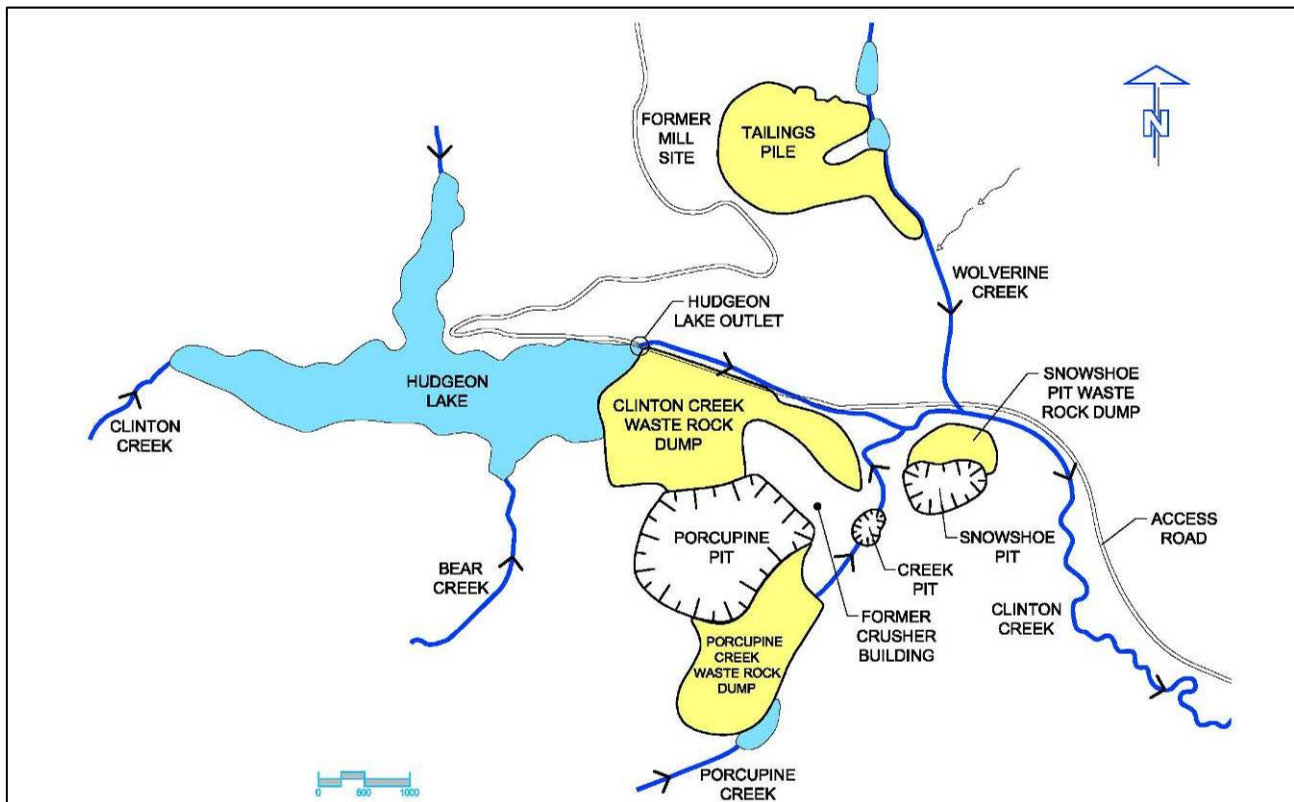


Figure 02 Mine Site Layout

2.3 Local Geology

Local geology consists of a complex assemblage of rocks that include ultramafic, igneous and metamorphic rocks such as serpentinite, diorite, amphibolite, schist, shale, siltstone and limestone (Stepanek and McAlpine, 1992). The ore body mined consists of chrysotile asbestos veinlets embedded in jade green serpentine. Of relevance to the current physical stability of the mine are intermittent outcroppings visible along the mine access road and creek channels. An orange coloured quartz-carbonate alteration is visible along the open pit wall and an outcropping along the mine access road at the confluence of Wolverine Creek and Clinton Creek. The rock is hard and durable compared to the sedimentary rocks and schists that commonly occur on the site and for this reason was quarried for use in the gabion baskets constructed to stabilize the outlet of Hudgeon Lake.

Weakly deformed shale, siltstone and sandstone are exposed along the Clinton Creek channel downstream of the Hudgeon Lake outlet (INAC, 1982). The rocks most visible along the portion of the Clinton Creek channel through the waste rock dump are platy graphitic argillite or mudstone. Cross beds up to 5 cm across are characteristic of the rock which is highly susceptible to mechanical weathering from creek channel flow and freeze-thaw action.

3. Active Mining (1968 – 1978)

3.1 Mine Operations

From 1968 until depletion of economic reserves in 1978, the Cassiar Mining Corporation (Cassiar) extracted approximately 12 million tonnes of serpentine ore from the three open pits. Over 60 million tonnes of waste rock from the open pits was deposited in the waste rock dumps. The ore was transported by an aerial tramway to the mill site located on a ridge along the west side of Wolverine Creek. Over the same period of time, about 10 million tonnes of asbestos tailings from the milling operation were deposited over the west slope of the Wolverine Creek valley. During its life, the ratio of waste rock to ore was in the order of 4 to 1 with waste rock hauled to the dump sites in 65 tonne dump trucks. Ore was trucked to the primary crusher located near the Creek Pit where it was screened and material greater than 100 mm was crushed in a jaw crusher. Eventually all material from the primary crusher was discharged onto a conveyor to the tramline feeder. The 1,600 m long tramline then raised the ore some 150 m to the mill site in buckets, each capable of carrying 1.5 tonnes of material.

The ore was dumped from the buckets at the mill's primary concentrator where the remaining waste rock was separated from the ore containing the majority of the free asbestos fibre. Further screening separated the throughs from the overs. The throughs were delivered to rotary kiln dryers to reduce the moisture content before storage at the dry rock storage building. In this dry state, the ore was regarded as mill feed material. The overs were re-screened and the secondary throughs were dried and transported to the dry rock storage building. The secondary overs were crushed again and the fines screened out and sent to the dry rock storage building. The remaining waste material or tailings were then deposited by conveyors to the tailings pile on the east side of the mill site.

An elevated conveyor within the dry rock storage building moved material into stockpiles according to grade, a procedure that facilitated blending of material as required. A loader was then used to move the material to the mill site which was capable of producing nearly 100,000 tonnes of asbestos annually. The mill further separated asbestos fibre from the host rock through a repetitive process of screening suction fibre lifting and cleaning until it was ultimately stored in one of the plants storage bins. The fibre was then bagged and loaded onto pallets for temporary storage before loading onto transport trucks and ultimate delivery to Vancouver and markets beyond.

3.2 Development of Waste Rock Dumps

Overburden and waste rock from the three open pits and crusher was deposited in either the Clinton Creek and Snowshoe Pit waste rock dumps on the south side of the Clinton Creek valley or the Porcupine Creek waste rock dump south in the Porcupine Creek valley (Drawing 01). Waste rock was disposed of by dumping on the slope of the respective valley walls. The total volume of waste rock is estimated to be 60 million tonnes (Roach, 1998). The waste rock typically consists of argillite, phyllite, platy limestone and micaceous quartzite (Stepanek and McAlpine, 1992). Asbestos fibres are occasionally found within the waste rock (RRU, 1999).

Placement of waste rock in the Porcupine Creek valley created a blockage of Porcupine Creek leading to minor ponding upstream of the waste rock dump. Shortly after dumping of waste rock into the Clinton Creek valley commenced, failures of the waste rock face occurred and the waste rock spread across the valley as more material was added. The failure history is not well documented, however, continued dumping and movement of the waste rock across the valley resulted in the eventual blockage of Clinton Creek and the formation of Hudgeon Lake upstream of the waste rock dump (Figure 03).

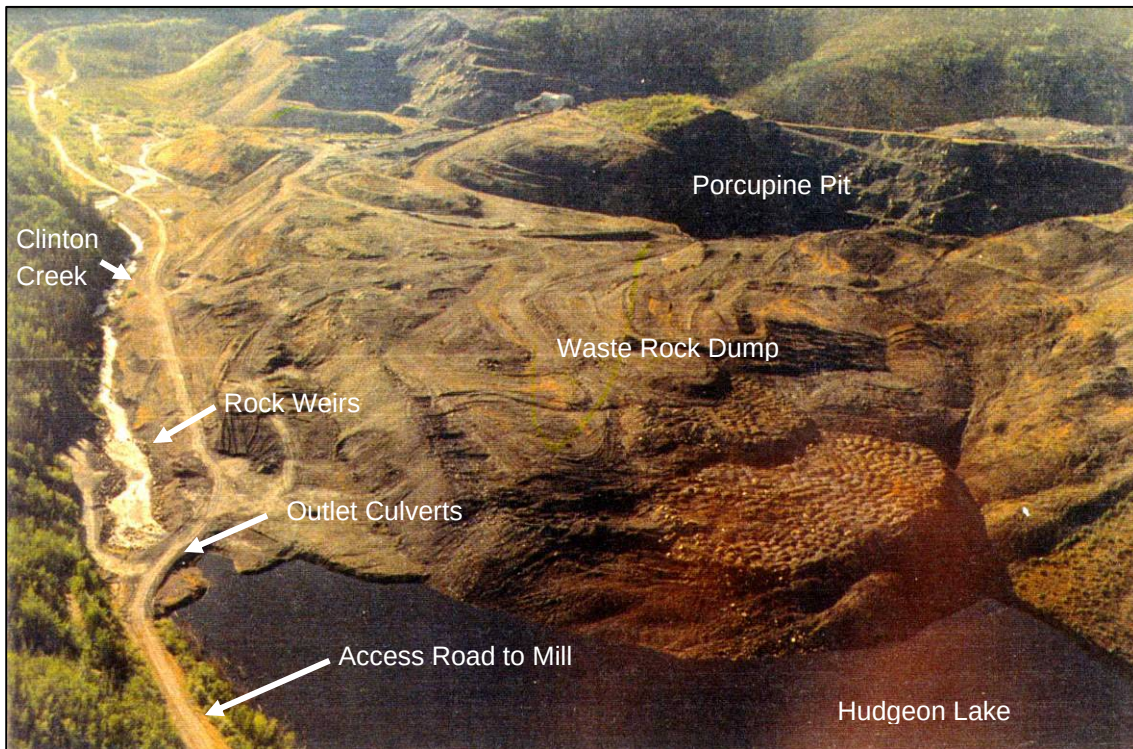


Figure 03 Clinton Creek Waste Rock Dump (1985)

By 1978, Hudgeon Lake was about 26 m deep comprising an area of approximately 73 ha (RRU, 1999). The elevated creek channel formed along the edge of the waste rock material and bounded by the north valley slope was about 0.8 km long with an overall gradient of 4.5 percent (Stepanek and McAlpine, 1992). Recognizing the potential for a breach of the waste rock plug at the outlet from Hudgeon Lake, the mining company initiated erosion control measures that included excavation of a channel and the installation of four culverts and a rock apron at the northeast edge of the waste rock where the access road to the mill crosses the channel. In 1981, rock weirs were constructed in the channel downstream of the culverts at the location shown on Figure 04. During the 1982 freshet, the creek escaped the armoured channel section and down-cut into the north valley slope. The armoured section was reconstructed in 1984 and during a high flow event in 1997, was almost completely destroyed.



Figure 04 Rock Weirs at Hudgeon lake Outlet (1985)

3.3 Development of Tailings Piles

About 12 million tonnes of mill tailings were deposited over the west valley slope of the Wolverine Creek valley. The tailings are composed primarily of serpentine and asbestos fibres. The original tailings deposit, referred to as the south lobe, failed in 1974 resulting in displacement of tailings to the floor of the deeply incised valley where flow in Wolverine Creek became blocked. This initial landslide blockage was almost immediately breached dispersing tailings as far as 2 km downstream (Stepanek and McAlpine, 1992). Cassiar constructed a series of rock weirs in 1978 to convey water over the south lobe. Following the failure of the south lobe and until closure of the mill in 1976, the tailings were deposited in the north lobe. Downslope movement of the north lobe began in 1978 and by 1985, the toe of the north lobe had reached the valley bottom, forming another pond (Figure 05). In 1978, Cassiar unsuccessfully attempted to stabilize both tailings pile lobes by partial regrading and terracing.

3.4 Geotechnical Inspections and Performance Monitoring

Beginning in 1974, numerous reports were prepared for both Cassiar and DIAND with respect to inspections of the physical stability of the waste rock dumps and tailings piles. These reports contain significant information regarding the installation of monitoring instrumentation, movement data, interpretation of monitoring results, etc. during active mine operations. The main points from the reports are summarized in the following sections. Anecdotal comments by the authors with respect to the excerpts are presented in italics.

One of the earliest reports was by Golder Brawner Associates who first reported instabilities of the waste rock dump and tailings (Golder Brawner, 1974). The report details the apparent lateral spreading of the waste rock and blockage of Clinton Creek. At the time, the depth of Hudgeon Lake was estimated to be 12 to 15 m. There was no flow in the channel and it appeared that its bottom had been elevated above the lake surface by waste rock movements. Failure of the south tailings lobe was also documented and recommendations were provided to begin tailings deposition to the north of the failed mass. This is also the

point in time when movement monitoring of both the waste rock pile and south tailings lobe were first recommended.



Figure 05 Wolverine Creek Tailings Pile (1998)

In early 1976, significant information was gathered with respect to instabilities of the waste rock dumps, open pit and tailings piles (Golder, 1977). Horizontal and vertical displacements of 7.9 and 4.6 m respectively were observed at the Clinton Creek waste rock dump. Horizontal movements were generally radial. By late 1976, deposition of waste rock had been diverted to the valley flat at the Snowshoe Pit waste rock dump. The small pond upstream of the Porcupine Creek waste rock dump was reported on in 1976 as was the occurrence of subterranean flow through the dump and into the Creek Pit. It was concluded that although movements of the Porcupine Creek waste rock dump were still occurring, these movements did not affect the discharge in Porcupine Creek. Instabilities of the west wall of the Porcupine Pit were also reported for the first time.

It was also speculated in 1976 that there was continued movement of the south tailings pile lobe although this could not be confirmed without installing movement monitoring points (which was done). It was concluded that while the north lobe was slumping at the top and moving downslope at the base, no sudden failures were expected. It was predicted that the north portion of the tailings (north lobe) would reach Wolverine Creek by about 1985. Recommendations were made to relocate the tailings conveyors to the northwest (onto the plateau area).

Conclusions were reached in 1977 that the waste rock material was very unstable, that continued encroachment on Clinton Creek could be expected and that it was impractical to stabilize the mobile mass (RM Hardy, 1977). There were no significant issues related to the performance of the Porcupine Creek waste rock dump and the small impoundment created as a result of the initial failure. Monitoring confirmed that movements of both the tailings lobes were occurring at rates that could be considered failure. With respect to the rehabilitation of the mine site, it was Hardy's opinion that consideration be given to stabilizing the creek channel through the waste rock since stabilization of the entire dump was not economically feasible. Some recontouring of waste rock could also be a consideration. It was considered likely that more failures of the tailings piles would occur and it was recommended that alternatives be considered to divert creek flow either through a culvert or in a stabilized channel at a higher elevation thus allowing increased toe loading to develop (Hardy, 1977).

4. Mine Site Decommissioning (1978 – 1992)

By 1978, the economic ore reserves had been depleted and the Cassiar Asbestos Corporation ceased mining operations. It is also our understanding that instabilities of the south wall of the Porcupine Pit may have been a factor in this decision (personal communication, B. McAlpine). The mill buildings and Town Site buildings were auctioned off in 1978. Between 1979 and 1987, structures from the Town Site and most of the mill structures and equipment were removed as part of decommissioning activities. The primary crusher, tramline towers, and an electric powered rotary drill are examples of some of the infrastructure and equipment that was not removed from the site over this period. Mass concrete structures and foundations at the mill site were also left in place.

After several years of monitoring and maintenance related to degradation and erosion of the creek channels through the waste rock dump and tailings piles, Cassiar proposed an abandonment plan. This plan considered the tasks for the waste rock dump complete and the most practical means of dealing with the tailings material was to maintain the Wolverine Creek channel until movement of the tailings had stabilized sufficiently so that a permanent channel could be made. A technical review of this plan carried out by Hardy Associates (1978) Ltd. on behalf of INAC advised of serious reservations with respect to the position that the waste rock and tailings piles would stabilize themselves and that abandonment of these piles in their present state was ecologically and socially acceptable (RM Hardy, 1978). Conceptual plans for constructing a system of weirs and sedimentation cells downstream of the mine (in association with limiting access) downstream of the confluence of Wolverine Creek and Clinton creek were provided by Hardy. The intent of the concept was to allow the abandonment of the mine in its current condition and allow natural processes to take place e.g. erosion of slumped material and the gradual lining of the creek channel(s) by durable rocks within the waste. The weirs and cells would provide a passive protection of the lower portion of the Clinton Creek valley and Forty Mile River.

Cassiar commissioned Kohn Leonoff in 1986 to prepare an abandonment plan for the mine. The plan concluded that the waste rock dumps and tailings piles were in a suitable condition for final abandonment and only minor work items required attention (Kohn, June 1986). These work items included removal of the culverts at the Hudgeon Lake outlet and removal of miscellaneous equipment. The plan was first submitted (in draft) to INAC for their review in June 1986. INAC requested further information be submitted supporting the rationale of allowing continued erosional processes to interact with continued downslope movement of the waste rock and tailings. INAC also requested that Cassiar provide a quantitative assessment of the associated risks and consequences resulting from hydrologic and seismic occurrences. They also recommended that the abandonment plan be submitted to the Yukon Water Board for their reaction. It is our understanding that the report was subsequently submitted to the Yukon Water Board in September of the same year.

A review of Cassiar's abandonment plan by Geo-Engineering in late 1986 (commissioned by INAC) concluded that the abandonment plan was deficient in the evaluation of potential impacts and in outlining future actions (RRU, 1999). It was recommended that the Yukon Territory Water Board request that Cassiar address these deficiencies and detail their contingency plan should the performance of the works not meet expectations. The Water Board held public hearings on the abandonment plan in January of 1987 and

subsequently recommended acceptance of the plan and an extension to the Water License to provide a means of regulatory compliance during mine abandonment. The Water Board also recommended that the \$400,000 Security Bond posted by Cassiar be retained to establish a monitoring and remote warning system to mitigate the potential risk of high water events associated with channel blockages (RRU, 1998). The DIAND Minister ultimately refused to sign the Water License amendment. The License thus expired and DIAND retained the Security Bond.

Cassiar retained Kohn Leonoff to prepare a report entitled “Downstream Hazard Assessment for Mine Abandonment” in December of 1987. The report was intended to satisfactorily address the concerns of INAC (DIAND) regarding final abandonment of the mine. The report concluded the waste rock dumps and tailings piles were considered to be in a safe condition for abandonment (Kohn, 1987). This conclusion was based on the observation that the ongoing movements of the waste rock dumps and tailings piles had sufficiently decreased and the Clinton Creek channel through the waste rock dump was in a stable configuration. A downstream hazard assessment conducted as part of this report concluded that only minor down-cutting of the Clinton Creek channel at the Hudgeon Lake outlet was likely to occur under a high (200 year) flow event and therefore the waste rock dumps did not represent a flood hazard to human life. A dam break analysis of the tailings piles showed that only minor increases in water levels in the downstream creeks and Forty Mile River were expected and therefore, the tailings piles also did not represent significant hazards to human life. The 1987 Downstream Hazard Assessment also determined the annual risk of human exposure (*immediately downstream of the mine within the Clinton Creek valley floodplain*) to downstream flooding associated with a breach event (*of either the tailings pile or waste rock dump*) was in the order of 1:25,000.

It should be noted that the 1987 risk calculation was determined based on a 20 year return period for a breach failure and a frequency of persons being in the flood plain of seven times per year for a one hour period. Subsequent evaluations concluded that the destruction of the rock weirs in 1997, continued channel down-cutting and increased frequency of occupancy in the flood plain would result in a significantly higher risk than stated in 1987 (UMA, 2000). It was determined however, that there was insufficient information to carry out a meaningful quantitative risk assessment in particular given the considerable uncertainty in parameters necessary to arrive at precise predictions of risk under various scenarios and circumstances.

Continued decommissioning of the mine site was carried out by Cassiar from 1987 to 1989 during which time the primary and secondary crushing units from the crusher building complex at the mill were removed (1988), warning signs were posted and additional mine site cleanup was carried out (1989). In 1991, Cassiar was bought out by the Princeton Mining Corporation who then undertook further remedial work including the re-establishment of signage, partial filling of the crusher building, remediation of the Hudgeon Lake outlet and other minor measures (RRU, 1999). In 1992 DIAND recommended that the Security Bond be returned to the Princeton Mining Corporation. For the purposes of this report, 1992 has therefore been considered the date that active mining and associated decommissioning work by the owner (Princeton) ceased.

4.1 Geotechnical Inspections and Performance Monitoring

Following the termination of active mining operations in 1978, numerous reports were prepared for Cassiar and DIAND with respect to inspections of the physical stability of the waste rock dumps and tailings piles

during the decommissioning of the mine site. These reports also contain information regarding the installation of monitoring instrumentation, movement data, interpretation of monitoring results, etc. during active mine operations.

A report was prepared for Cassiar by Golder Associates in 1978 at the completion of active mining operations summarizing geotechnical investigations carried out to evaluate the mechanism of earth movements and describe possible measures to remediate erosion problems associated with the earth movements. Based on average creep movements of the Clinton Creek waste rock dump, it was reported that 1.1 to 1.2 m of waste rock was being eroded from the right hand (waste rock) side of the channel annually (Golder, 1978). Slope stability analysis concluded that high pore water pressured at the base of the dump, resulting from permafrost degradation, was responsible for the horizontal spreading across the valley (Golder, 1978).

By 1978, the downslope movement of the 1974 failure of the south tailings lobe had decreased considerably to a reported value of 3.3 mm/day. At the same time however, the north lobe was continuing to move at an estimated rate of 64 mm/day and was now within about 107 m of Wolverine Creek. It was estimated that the north lobe would reach the edge of the pond created by the south lobe by 1983 showing fairly good agreement with the 1976 prediction of this occurrence. The rate of channel closure (and hence erosion) along the leading edge of the south lobe was estimated to be 1.2 m/yr. Analysis indicated that off-loading the tailings piles in combination with grading and lining of the Wolverine Creek channel could significantly improve their stability (Golder, 1978). A rock lined channel was subsequently installed in 1978 to convey Wolverine Creek over the extreme southern portion of the tailings pile in the valley bottom (Hardy, 1985).

Options to deal with the ongoing instabilities of the waste rock dump and channel erosion along Clinton Creek where it ran along the leading edge of the waste rock were evaluated in Golder's 1978 report. These included:

- 1) status quo (no treatment),
- 2) transverse groynes (*rock structures perpendicular to the channel to maintain channel grade*), and
- 3) infilling the existing and reconstructing a raised channel,

As part of evaluating Option 3) above, it was estimated it would be necessary to raise the north edge of the waste rock dump to about elevation 417.6 m to achieve a factor of safety of 1.25. This would require raising the level of Hudgeon Lake some 7.6 m above the existing level and gradually dropping the channel through the waste rock through a series of energy dissipating weirs.

It was postulated that the mechanism for failure of the south tailings lobe was the build-up of excess porewater pressures within the active layer beneath the tailings in the naturally occurring draw in the valley slope between the tailings lobes allowing continuous but slow downslope movements. When more resistance to sliding was encountered, the tailings mass accumulated farther upslope causing increased pore water pressures and driving forces that eventually triggered the large failure in 1974. Once the south lobe reached the bottom of the valley, it began to spread laterally and it was thought that stability was increasing due to temperature equilibrium between the tailings and foundation soils and dissipation of excess pore

water pressures (Golder, 1978). Failure of the north lobe was attributed to thaw-consolidation of the permafrost affected foundation soils beneath the tailings.

With regard to solutions to deal with the instabilities of the tailings piles, the 1978 report identified regrading of the upper portion of the lobes and grading and lining of the Wolverine Creek channel across the south lobe as the most practical solution. It was also believed that concerns regarding fugitive dust from the tailings would abate once milling operations ceased and a wind resistant crust would form on the tailings (Golder, 1978). Immediately south of the tailings, it was recommended that the channel be lined and a series of weirs be installed to drop the elevation of the elevated creek channel some 19.2 m over a distance of about 213 m to the natural creek channel bed.

R.M. Hardy & Associates Ltd. prepared a report to the Northern Affairs Program in October 1978 summarizing the current status relative to the rehabilitation plan for the mine which by this time had ceased active ore extraction (Hardy, 1978). As part of this report, the stability of the recontoured tailings pile under dynamic (seismic) loading conditions was evaluated. The analysis showed it was possible that the factor of safety against failure due to excess pore water pressure in the weathered argillite may not be adequate. It was recommended that Cassiar be requested to produce a contingency plan which would illustrate the rehabilitation plan for Wolverine Creek in the event of a massive failure of the north lobe and that movement monitors destroyed during recontouring of the tailings be replaced.

From 1979 to 1981, continued movement of the waste rock into the creek channel was observed at rates ranging from 46 to 100 cm/yr in the winter to as high as 52 to 152 cm/yr in the summer (Hardy, 1981). It was concluded that the waste rock dump was unstable and continued movements could be expected although a sudden and catastrophic movement was not anticipated. Continued erosion of the channel flanks, including the bedrock was observed and the deterioration of the rock weirs installed at the outlet was noted. Retrogressive down-cutting of the channel was reported to be of concern (Hardy, 1981). *It appears that at that time (summer of 1981), Cassiar had plans in place to repair the weirs and this work was carried out in the fall of 1981.*

Over the same monitoring period from 1979 to 1981, continued and possible accelerating movements of the tailings piles were reported. Horizontal movement rates of 28 to 287 cm/yr were measured at the south lobe at individual monitoring points during the summer of 1980 and 1981. Horizontal displacements over the winter ranged from 15 to 284 cm/year. Vertical (downward) movement rates of 18 to 107 cm/yr were reported although upward movement was observed at the toe area. It was concluded that the south lobe was experiencing mass readjustment at rates that were not decreasing and in fact may be increasing in the toe area. These movements however, were not considered to be indicative of a sudden and catastrophic slope movement (Hardy, 1981).

A significant increase in movement rates was observed over the 1980-1981 season at the north tailings lobe with horizontal displacement rates ranging from 12 to 950 cm/yr and from 18 to 1192 cm/yr in the summer and winter respectively. Vertical movements reached maximum values of 5.5 m/yr over the same period. These rates were considered relatively rapid. It was postulated that the north lobe was moving in individual segments rather than as a single mass. It was also concluded that the recontouring in 1978 had not arrested the movements and the likelihood that the lobe would reach the valley bottom was considered to be high.

The rock weirs constructed at the south limit of the tailings were in good condition although the structural integrity of the last three weirs was poor (Hardy, 1981).

An inspection of the mine site in June of 1982 showed continued movement of the waste rock material, apparently at the same rate as previously reported. Significant bank erosion (in particular the left bank) and deterioration of the weirs at the Hudgeon Lake was observed and remedial work including the removal of the culverts was considered necessary (Hardy, 1982). Although movement data was not available, it was readily apparent in 1982 that the tailings piles were continuing to move, perhaps at an accelerated rate. It appeared that the north lobe had experienced the greatest deformations. Once again, it was predicted that the north lobe would eventually reach the valley bottom.

In August 1983, Klohn Leonoff prepared a report on the mine waste dumps followed by a November report summarizing remedial work carried out in the fall (September) of 1983 that included the relocation of the Clinton Creek channel away from the eroded left bank, plugging of the upstream end of the eroded channel, and excavation of an emergency overflow channel in the road embankment at the outlet. A review of slope movement data from the tailings piles was carried out in early 1984 for INAC (Hardy, 1984). The report concluded that horizontal creep movements of the south tailings lobe in the order of 150 cm/yr were occurring. Accelerating movements of the toe of the north lobe were reported and it was predicted that a failure would occur by 1986 (Hardy, 1984). Several reclamation schemes were evaluated and the most practical and economical of these appeared to be the construction of a dam at the toe of the south lobe to about elevation 429.8 m. Corrugated steel pipes would be installed through the dam to convey water in Wolverine Creek. The program of inspection and unspecified maintenance was not considered to represent the most practical strategy for controlling erosion of the tailings.

An inspection of the waste rock dump and tailings piles was carried out for Cassiar by Klohn Leonoff in June of 1984. As part of this inspection, surveys of movement monitoring points and a Clinton Creek channel profile were carried out. Minor erosion of the Clinton Creek channel immediately downstream of the culverts was observed (Figure 06) but overall, it appeared that the erosion protection works carried out in 1983 (Klohn, 1984) were performing satisfactorily. It was recommended that the geotextile filter which was planned to be installed beneath the apron riprap be eliminated. No significant changes in the channel profile further downstream were observed although freshly exposed slopes of waste rock indicated some creep movements were continuing. *This can be corroborated by horizontal and vertical (settlement) movement rates ranging from 39 to 64 cm/y and 8 to 62 cm/yr respectively.*

Based on observations in June of 1984, it was determined that the tailings piles were continuing their large downslope movements and by this time, the toe of the advancing north lobe had reached the edge of the pond upstream of the south lobe (Figure 07). Horizontal and vertical movement rates ranging from 56 to 585 cm/yr and +82 to -208 cm/yr respectively were measured at the south lobe indicating an increase over the rate observed in 1983. At the north lobe, horizontal and vertical movement rates ranging from 5 to 3313 cm/yr and -5 to 893 cm/yr respectively were measured. The largest movements were near the toe and were consistent with rates determined for 1983. The channel lining and weirs constructed to convey Wolverine Creek over the south extent of the south lobe were performing well (Klohn, 1984). Measurements taken of these works showed a minimum bottom width of about 9.1 m and an effective depth of about 1.2 m. It was concluded that while some minor erosion of the tailings was expected over the next year, the channel was

safe against major blockages. A strategy of continued observation and maintenance as required was recommended until such time as a long term solution could be designed and constructed.



Figure 06 View U/S at Hudgeon Lake Outlet (1984)

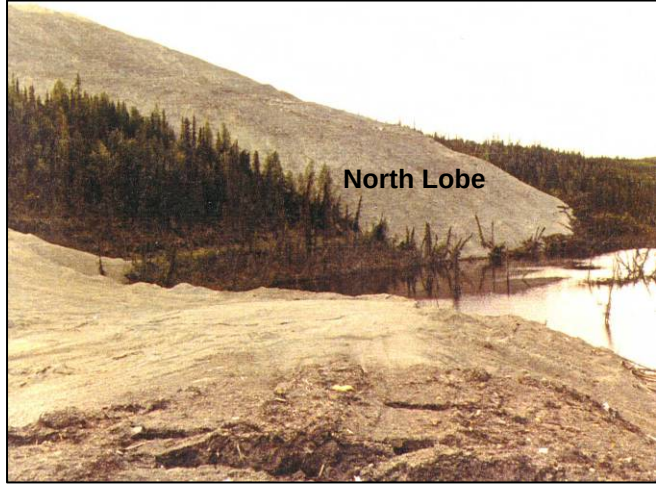


Figure 07 Tailings Pile (1984)

The Clinton Creek valley downstream of the confluence with Wolverine Creek was examined in 1986 to determine the amount of sediment transport after the 1974 failure of the south tailings lobe (Geo-Engineering, 1986). The following observations were made:

- The Wolverine Creek valley up to the confluence with Clinton Creek had been covered by tailings and the creek was downcutting through the sediment,
- Extensive deposits of asbestos fibres and sand size tailings exist along Clinton Creek up to 5 km downstream from the Wolverine Creek confluence,
- Asbestos fibres were visible in trees some 2 m above the floodplain elevation along Clinton Creek about 2 km downstream of the Wolverine Creek confluence. Fibres were also noted approximately 4.2 m above the normal level of the creek 3 km from the Wolverine Creek confluence, and
- Serpentine and argillite fragments were noted in the alluvial fan at Clinton Creek's confluence with the Forty Mile River (the source was considered to be undetermined).

Inspections of the mine site carried out by Geo-Engineering for the Northern Affairs Program (INAC) in June of 1987 concluded that both the waste rock dump and tailings piles were continuing to move at previously observed rates (Geo-Engineering, 1987). The 1987 Geo-Engineering report also provided the first observations of the Porcupine Creek waste rock dump since 1976. Ongoing instabilities forming a complex instability zone encompassing the entire waste rock dump were evident. The slumping waste rock had blocked creek flow forming a small upstream pond. Water from the pond drained either along the toe of the waste rock or as underflow through more permeable zones within the waste rock. Further downstream, the flow united into the valley bottom. No major sediment transport was expected since creek flows were small.

Inspections were again carried out in June of 1988 for the Northern Affairs Program by Geo-Engineering. Waste rock movements were observed to be similar to previously identified with no significant changes noted. Small slides were observed along the Hudgeon Lake shoreline and it was suspected that water levels in Hudgeon Lake the previous year had been 1.5 m above the level observed during the site visit (Geo-Engineering, 1988). Minor erosion and downcutting of the creek channel downstream of the Hudgeon Lake outlet were observed. Continued movement of the Porcupine Creek waste rock dump had almost completely blocked the valley and outflow from the pond was now entirely through (below) the waste rock. The most active areas of the tailings piles were reported to be along the toe of the south pile where rates of horizontal movement in the order of 5 to 10 m/yr underflow were estimated. Displacement of the north lobe was reported to have decreased because of support provided by the east valley wall. It was apparent that the north lobe had blocked drainage and the blockage had been breached and a channel cut through the tailings.

Geo-Engineering conducted another inspection in September of 1990 on behalf of the Northern Affairs Program. Fresh scarps were noted in the uppermost section of the waste rock dump and it was apparent that the toe was continuing to advance into the creek channel. Minor downcutting and erosion of the channel was reported to be continuing although with no major impact on the rock weir downstream of the Hudgeon Lake outlet. It was concluded that during the past 10 years, the volume of material moving into the creek channel had been relatively constant and all but the larger particle sizes, had been transported further downstream. The highest risk to the stability of the waste rock dam was the breaching and erosion of the armoured section which could result in the release of a large volume of water. Examples of landslide dams formed by slumps were provided for comparison to the Clinton Creek site (Geo-Engineering, 1990).

Rates of movement at the Porcupine Creek waste rock dump appeared to have increased in 1990. This was the first year when observations of the condition of the Snowshoe Pit waste rock dump were reported; although there was evidence that the dump was unstable, there was not expected to be any significant impact on the Clinton Creek channel because of the small volumes of material that would be involved. It was estimated that movements of the south and north lobe at the tailings were in the order of several metres per year to ten or more metres per year respectively. The height of the north lobe in the valley bottom was increasing causing the size of the upstream pond to increase.

5. Post Mine Site Decommissioning (1992 to Present)

Inspections in 1991, 1992, 1995 and 1996 by Geo-Engineering confirmed that while movements of the waste rock dump and tailings were continuing, their overall condition had not significantly deteriorated (Geo-Engineering, 1998). However, in June of 1997, a considerable flood event occurred and significantly modified the Clinton Creek channel between the waste rock dump and Wolverine Creek. The event caused significant erosion of the channel through the waste rock as evidenced by material deposited downstream of the dump. Further downcutting and widening of the channel through the waste rock was evident and the armoured section of the channel immediately downstream of the Hudgeon lake outlet was almost completely destroyed. Retrogression of the channel downcutting appeared to have terminated about 20 m downstream of the un-armoured lake outlet. The event appeared to have been less intense along Wolverine Creek with only minor widening of the channel through the un-armoured section of the tailings and overtopping of the culvert at the road. The rock weirs on the south lobe appeared to have performed well.

By 1998, downcutting of the Clinton Creek channel downstream of the Hudgeon Lake outlet was becoming increasingly significant and compounded by heavy seepage along the sides of the waste rock channel (Geo-Engineering, 1998). Movement of the waste rock dumps and tailings piles was also observed to be continuing. Subterranean flow through the Porcupine Creek waste rock dump was still occurring and the outlet was now elevated some 4 m upslope of the road. Rehabilitation of the Hudgeon Lake outlet was recommended in 1998 (Geo-Engineering, 1998), followed by the submission of a number of reports on the environmental and physical stability of the mine. These reports and their findings are described in the following sections.

5.1 Environmental Review of the Abandoned Clinton Creek Asbestos Mine

In 1998, the Applied Research Division of the Royal Roads University (RRU) was retained by Indian and Northern Affairs (INAC) Canada to prepare an Environmental Review of the abandoned Clinton Creek Asbestos Mine (RRU, 1999). As part of this review, a field investigation was conducted in September 1998 by a team comprising participants from DIAND, RRU and W.R. Ricks Consulting.

5.1.1 Assessment of Aquatic Habitat and Resources

During the field investigation, an inventory and assessment of aquatic habitat and resources was carried out in the Clinton Creek watershed for comparison with a similar assessment carried out in 1980. The significant findings from the aquatic habitat assessment are as follows:

- Overall, the most significant change in fish habitat appeared to be 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 the lower zones of Clinton Creek remained relatively stable and were similar in characteristics to a reference location in Mickey Creek,

- There was 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, and
- There were no significant improvements observed in the arctic grayling population in Hudgeon Lake.

5.1.2 Assessment of Terrestrial Habitats

A quantitative assessment of terrestrial habitats was conducted using ground cover vegetation surveys in representative areas directly or indirectly affected by mine waste. The findings are as follows:

- Ground vegetation in the tailings area was extremely scarce and plant diversity low,
- Indirect effects of smothering from the tailings were evident,
- Ground vegetation species at the waste rock dump were not unlike that of the tailings pile,
- The re-establishment of trees and vegetation in general was greater at the waste rock site than at the tailings pile, and
- Observations of chrysotile asbestos in the lower branches of trees at a height corresponding to the winter snow pack suggested some potential for the mobilization of asbestos in the terrestrial environment.

5.1.3 Geochemical Assessment

A geochemical assessment of the waste rock and tailings materials was undertaken to determine the potential impact of these materials on the surrounding aquatic environment. A total of 32 soil samples were taken from the mine site and 27 water and 23 sediment samples were taken from Hudgeon Lake, Wolverine Creek, Forty Mile River and three reference locations. The samples were analyzed for metals, metalloids, and asbestos. Inorganic non-metallic parameters were also determined in the water samples. The major findings are as follows:

- Soil and water samples consistently showed elevated pH indicating alkaline conditions,
- Antimony, lead, molybdenum, silver and tin were generally below the detection limits in soil/sediment samples,
- Concentrations of arsenic, barium, chromium and nickel exceeded the CCME Guidelines (of the day) or residential parkland use in substrate samples. These elements were not detected in water samples as the high pH of the soil likely keeps the metals out of solution and their mobilization into surrounding waters,
- Asbestos concentrations in water were elevated but comparable to previous results,
- An anoxic condition was noted at depth in Hudgeon Lake, and
- Concentrations of aluminum, iron, manganese and selenium in a number of water samples were above the CCME Guidelines for freshwater aquatic life or drinking water. It was determined that manganese could be eliminated as a metal of concern unless humans use the surface water for drinking water supplies. Given the natural geological conditions in the area, it was considered unlikely that aluminum, iron and selenium in freshwater had resulted in elevated risks to aquatic or terrestrial receptors in the vicinity of the rivers and creeks.

5.1.4 Conclusions and Recommendations

Conclusions reached included the following:

- Ecological receptors at risk from the chronic mobilization of waste rock and tailings included terrestrial mammals, including humans and asbestos inhalation, aquatic animals e.g. beavers, anadromous fish populations e.g. salmon and non-anadromous fish populations,
- Chronic risks associated with geochemical mobilization and release of metals/metalloids or other substances to the water appeared unlikely,
- Anoxic bottom waters in Hudgeon Lake may be representative of the 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 impact from a catastrophic failure of the waste rock dump or tailings would be 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 deemed to merit further assessment of risks included anadromous and non-anadromous fish populations and habitat and fish forage species such as aquatic invertebrates. It was determined that terrestrial ecological receptors, other than humans, could provisionally be excluded from a more detailed ecological risk assessment (unless unique species are identified), and
- Human health related risks which merited further examination included cancer risks from the inhalation of friable chrysotile asbestos fibres based on occasional visits to the area, cancer and other health risks from the ingestion of water with elevated levels of chrysotile asbestos fibres, and the risk of loss of life, other traumatic injury or of property damage due to severe flooding.

5.2 1998 Site Reconnaissance

At the request of InAC, UMA completed a one day site reconnaissance in August of 1998 followed by a more detailed reconnaissance in September of 1998 in conjunction with site work underway by RRU (UMA, 1999). The purpose of the two trips was to inventory all pertinent site conditions relative to the extent of existing slope movements of the waste rock dump and tailings piles and assess any visual indicators of potential continued movement. Observations made during the reconnaissance trips were compared with historical photos to assist in determining the progression of movements and physical changes of the mine site elements. Observations made and conclusions drawn are summarized as follows:

- Significant down-cutting of the channel bottom and under-cutting of the channel banks was continuing along Clinton Creek where it passed over the waste rock dump. The risk of a partial or complete breach of the waste rock plug at the Hudgeon Lake outlet was identified. Associated with a breach was the likelihood of flooding and debris flows more destructive than had been seen historically e.g. much more severe than in 1997. The gradual loss of the access road was also occurring as a result of localized channel bank instabilities. Continued lateral spreading of the waste rock into the channel was believed to be likely as the channel is down-cut,

- Significant instabilities of the Porcupine Creek waste rock dump were evident and impounded water upstream of the waste rock continued to flow in subterranean channels along the toe of the waste rock and deeper along the valley floor. A potential for blockage of these flow paths that could result in water overtopping the waste rock along the east valley slope was identified,
- Continued advancement of the north and south tailings lobes into the Wolverine Creek valley, and subsequent erosion along the leading edge of the tailings was observed. It was recommended that movement monitoring information be obtained to comment further on the potential for a large mass movement that would result in a significant channel blockage and subsequent breach (similar to the 1974 event), and
- The consequences of a breach of the waste rock and tailings blockages included the potential for loss of life associated with flash flooding and debris flows. The mine site has public access and placer mining was underway along both creek channels at the time of the reconnaissance.

5.3 1999 Site Reconnaissance, Site Surveys and Photogrammetric Mapping

UMA carried out a site reconnaissance in July 1999 to further evaluate conditions observed in 1998 at the Clinton Creek waste rock dump, assist with site surveys, and establish targets for photogrammetric mapping. Slumping of the valley slope and waste rock along the north and south sides of Clinton Creek through the waste rock dump was evident, in particular 350 m downstream of the Hudgeon Lake outlet. Open channel flow terminated in Clinton Creek at the east end of the waste rock, reappearing about 100 m downstream of the washed out access road bridge. The survey included the establishment of mine grid coordinates of photo-identifiable points for photogrammetric mapping (aerial photography), the locations of movement monitoring targets, channel closure sections in the waste rock dump and representative cross sections and a channel bottom profile along Clinton Creek through the waste rock dump.

Attempts to locate previous mine site benchmarks were largely unsuccessful and new benchmarks were established. The coordinates and elevation of the benchmarks were determined using UTM coordinates and reconciled with the mine site (local) grid. As many previous movement monitor targets as could be located and a number of targets for cross-channel reference lines e.g. J-JJ were tied in using UTM coordinates. A survey of the Clinton Creek/Wolverine Creek confluence was also carried out. Aerial photography originally planned for the summer of 1999 was delayed due to smoke from forest fires in the area. Geographic air of Edmonton flew the site in September 1999, completing three lines across the mine site in an east-west alignment and a single line along the Clinton Creek channel from the mine site to the confluence with the Forty Mile River. Stereo pairs of photos were produced at a scale of 1:10,000 and digital orthophoto image mosaic files were prepared.

5.4 Condition Assessment Report

INAC retained UMA to prepare a summary report of the physical and environmental conditions at the Clinton Creek Mine site based on observations documented in previous studies and information collected during recent investigations undertaken by UMA Engineering and Royal Roads University in 1998 and 1999. This report reiterated observations of continued waste rock and tailings pile movements.

5.5 Risk Assessment Report

A qualitative risk assessment was carried out by UMA in 2000 utilizing the observations made since cessation of active mining with respect to the physical stability of the waste rock dumps and tailings piles (UMA, 2000). The purpose of the work was to determine the potential downstream hazards and risks associated with a breach of channel blockages created by landslides of the waste rock and tailings. Subsequent to the findings of this initial phase of work (Phase 1), it was anticipated that the overall project would proceed in one of several directions based on whether i) the risk was deemed unacceptable, ii) the risk could not be quantified, or iii) the risk was considered acceptable, as illustrated in Figure 08. The work undertaken was divided into three unique tasks; 1) data review and collection, 2) hydraulic modelling, and 3) risk assessment as part of a Phase 1 program.

5.5.1 Data Review and Collection

Data related to precipitation, hydrology, etc. was collected for use in the hydraulic modelling. Any relevant flow measurements for Clinton Creek, Wolverine Creek and the Forty Mile River were obtained. A literature search was also completed to determine breach characteristics of man-made dams and natural valley blockages to develop a range of likely breach scenarios for the mine site. Several important observations came from this review, most notably the observation that channel down-cutting in the Clinton Creek channel through the waste rock had worsened and retrogressed towards the lake outlet. This observation was made based on a comparison of the channel profile in July 1986 and July, 1999. Although there was a considerable gap in the movement monitoring data, the 1999 survey indicated that horizontal waste rock movements, while continuing to occur, were diminishing. The average rate of movement (over 13 years) was estimated to be in the order of 10 cm/yr compared to rates as high as 120 cm/yr measured in 1978.

5.5.2 Hydraulic Modelling

A dam breach model was developed to determine the implications of a breach of the Clinton Creek and Wolverine Creek valley blockages. A range of potential breach geometries were evaluated to assess the consequences from a variety of breach scenarios. The implications in terms of water levels, extent of inundated area, warning period and sediment transport for the breach scenarios were quantified.

The 200 year flood peak at the Hudgeon Lake outlet was estimated to be 43 m³/sec compared with 78 m³/sec estimated in 1987. The difference in estimates is attributed to 13 additional years of records and the inclusion of smaller drainage basins in Alaska in the vicinity of the project. The 200 year flood peak for the Wolverine Creek basin at the tailings piles was estimated to be 17.1 m³/sec. Based on depth soundings by RRU in 1998, the volume of water in Hudgeon Lake was estimated to be in the order of 12 million m³. Using 1:50,000 scale NTS map sheets from 1959 (prior to mine development), UMA independently estimated the volume at the current lake level to be 9.4 million m³. The total volume of water in the pond upstream of the tailings along Wolverine Creek (at the time of a breach) was estimated to be 1 million m³.

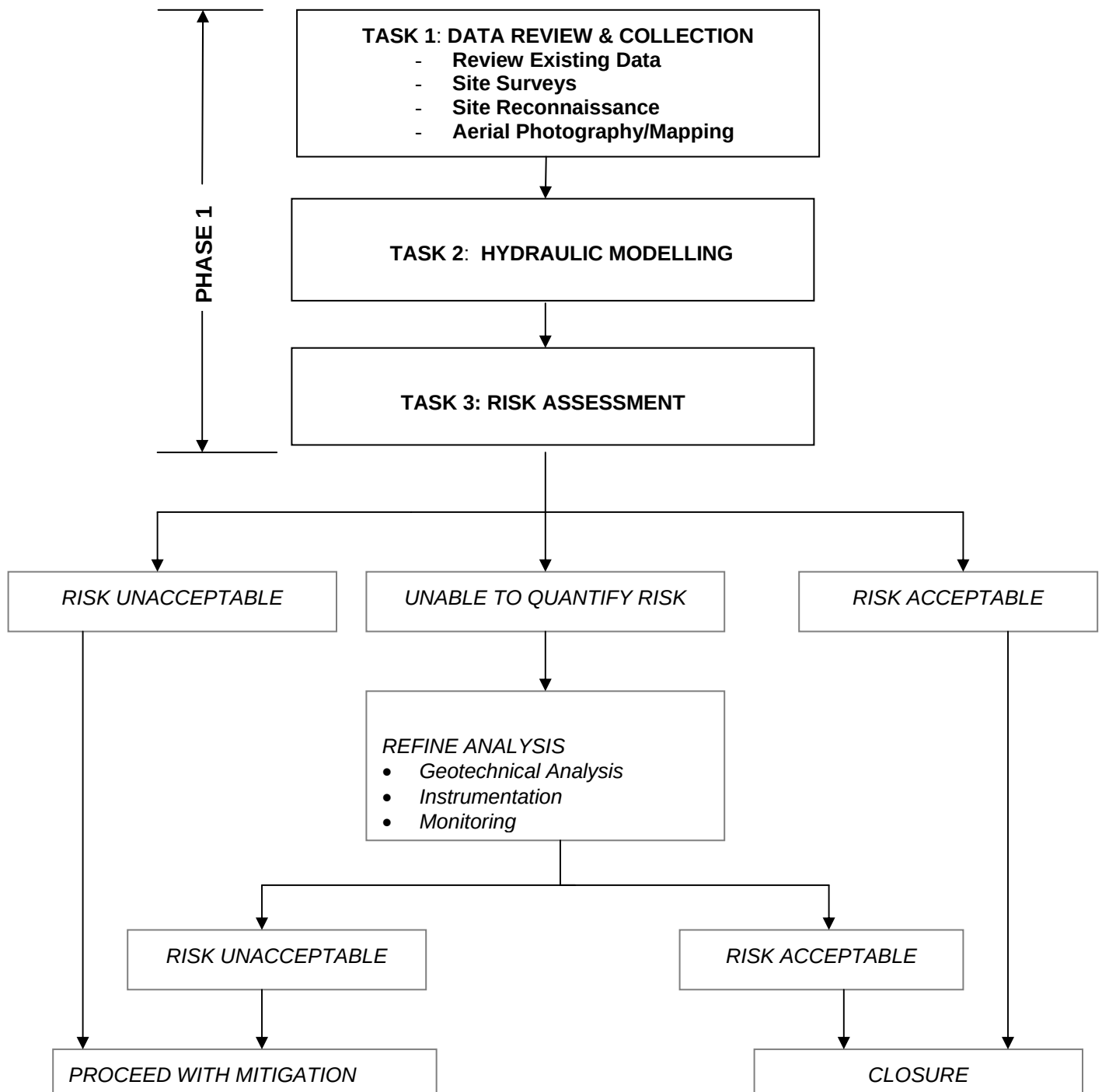


Figure 08 Risk Assessment Model

In most dam breach failures, including natural landslide dams, the resulting breaching mechanism involves the erosion of the embankment material by the flow of water over or through the blockage. The potential breach characteristics were determined using case histories in comparison to the size of the waste rock dam, the material properties of the waste rock and the method of deposition. Because of the relatively long and flat downstream face of the channel through the waste rock downstream of the Hudgeon Lake outlet, a breach failure due to overtopping was considered much more likely than a failure due to internal erosion (piping). The failure mode was therefore assumed to be overtopping with the width of the breach limited by the valley slope to the north and waste rock mound to the south, a distance of about 140 m. It was considered unlikely that the relatively flat upstream slope extending into Hudgeon Lake, likely comprised of fine grained unconsolidated material would provide much erosion protection once a breach was initiated. Four breach scenarios were considered with the worst cases being the full breach scenario where the entire lake drains (Scenarios 1. and 2.):

1. Full breach based on empirical data (case histories),
2. Full breach controlled by bedrock along the valley slope,
3. Rapid channel downcutting (as per the 1987 Klohn report),
4. Partial breach (in the order of 10 m deep)

The peak flows, elevation, velocity and time to peak flow were determined for each of the four scenarios at different locations downstream of the waste rock dump. In all cases, a peak discharge of approximately 500 m³/s at a maximum flow velocity of 3.5 to 4 m/s is reached, corresponding to flow depths of 2.1 m at the confluence with Wolverine Creek. The flood peak attenuates quickly and reaches a base flow at the valley constriction downstream of Wolverine Creek. The flow velocity between the waste rock dump and valley constriction ranges from 1.1 to 3.0 m/s which is sufficiently high to move coarse bed material ranging up to 1.4 m in diameter. Due to turbulence in the channel flow, finer grained material would be transported well beyond the valley constriction.

Based on observations of the performance of the tailings piles and estimated depth to bedrock (which would control the depth of a breach), a breach geometry for the tailings blockages was determined. During minor closures, the tailings would be washed away almost immediately and there would be insufficient time to store a large volume of water upstream of the tailings. The worst case scenario would be a sudden full blockage to an elevation of about 411.6 m (the current toe elevation). It was estimated that the resulting peak discharge would be approximately 350 m³/s corresponding to a flow depth of approximately 3.4 m. The peak flow was high due to the short breach time, the steep channel profile and the lack of flood plain storage along the creek. As a result, the full volume of the breach outflow would be carried downstream to Clinton Creek where it would go into storage on the flood plain. The water level would peak at the valley constriction and diminish as the flood wave progresses further downstream.

5.5.3 Risk Assessment and Downstream Hazards

Development of channel blockages and continued erosion and downstream deposition of waste rock and tailings materials presents concerns in the context of consequences associated with i) chronic conditions from ongoing sedimentation and ii) catastrophic conditions associated with a breach. With respect to chronic conditions, it was estimated that approximately 1,000 m³ of waste rock erodes each year. The impact would

be most significant immediately downstream of the waste rock dump where the coarser material is deposited. Finer fractions would be carried farther downstream. Through the continuous erosion of waste rock and the deposition of coarse material in the general area of Wolverine Creek, Clinton Creek will cut new channels in the area during larger floods, possibly as often as on an annual basis. The volume of tailings eroded on an annual basis was estimated to range from 7,500 to 15,000 m³/yr. It was estimated that up to 50 percent of this material reaches Clinton Creek during normal flows where it is distributed downstream as far as the Forty Mile River. *Recent movement monitoring data indicates that the rates of erosion of waste rock and tailings are significantly lower than previously assumed (UMA, 2006).*

The conditions at the former mine site in 2000 (prior to stabilization works) potentially exposed individuals, property and the environment to some degree of risk mainly associated with catastrophic flooding. Using available information, a qualitative assessment of risk scenarios and human and ecological exposure levels associated with a breach of the channel blockages of Clinton Creek and Wolverine Creek outlet was possible. A quantitative estimate of risk was not considered appropriate given the considerable uncertainty in parameters necessary to arrive at precise predictions of risk under various scenarios and circumstances. There was however, sufficient reliability in the results to determine the acceptability of potentially hazardous activities and develop guidelines for appropriate risk management strategies. In this regard, the level of risk downstream of the mine site was categorized as high, medium or low based on the severity of flooding within each zone. The inherent risk to human health and potential loss-of-life is dependent upon the potential for human exposure within these zones. These risks can be broadly placed into public safety and ecological and health risk.

In terms of public safety, the level of risk downstream of the mine site should a breach of the waste rock plug occur was categorized as high, medium or low based on the severity of flooding in each zone (Figure 09). The inherent risk to humans and the potential for loss-of-life is dependent upon the likelihood of exposure (occupancy) within these zones. The potential for loss-of-life is greatest immediately downstream of the mine site in the area potentially inundated by a breach of the Hudgeon Lake outlet. Farther downstream along Clinton Creek, the risks are reduced, as the high water levels will be confined to the creek valley below the road where human exposure is less likely. The risk is considered low at the next most likely downstream area of occupancy in the vicinity of the former Clinton Creek Town Site where the valley widens considerably. Aquatic life and mammals downstream of the mine site are potentially at risk from the redistribution of eroded waste rock. The largest risk is believed to be from a sudden breach of the waste rock dump resulting in fisheries habitat loss through downstream smothering and flooding.

A hazard zone summary table was provided identifying potential occupancy, the hazard rating (H, M or L), and the potential consequences of occupying these zones in the event of a catastrophic breach. A number of immediate risk management measures were identified to deal with each of the ecological or human health risks identified. These were:

- Preventing vehicle access to high hazard areas,
- Prohibiting camping in high hazard areas,
- Posting warning signs, and
- Providing camping facilities on sufficiently high ground within low or medium hazard areas.

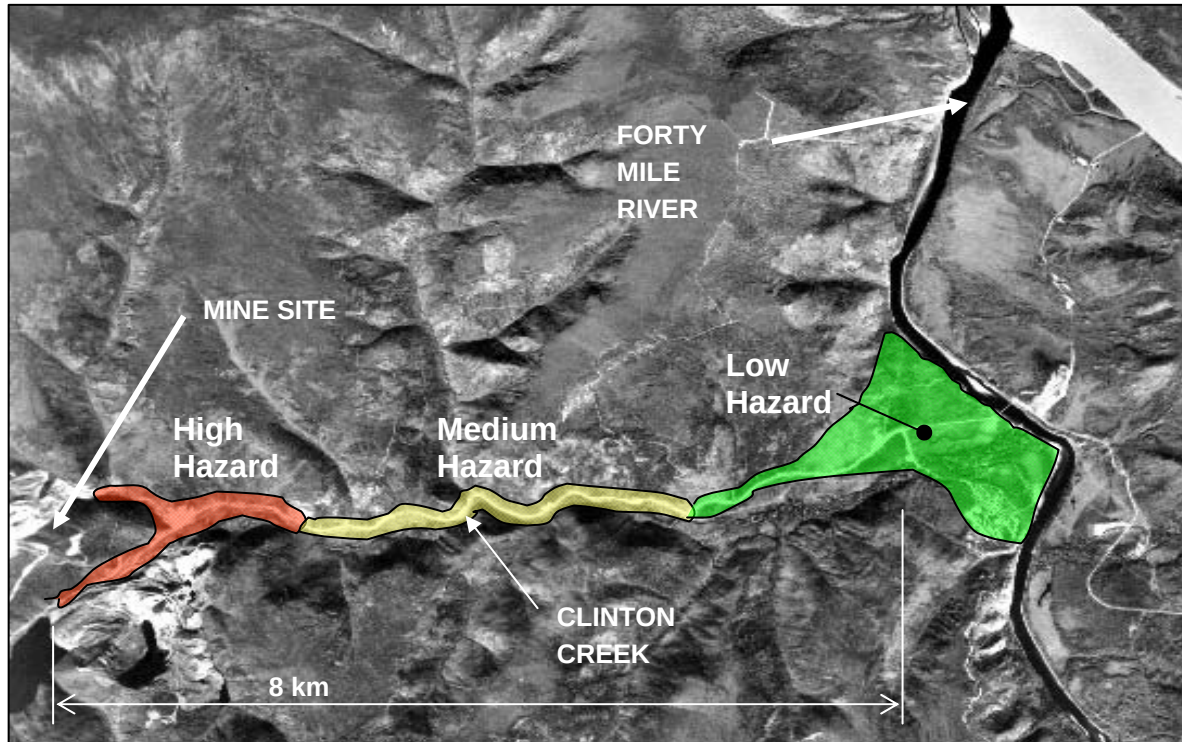


Figure 09 Downstream Hazard Mapping

5.6 Conceptual Design Report

In June of 2002, UMA prepared a report for Indian and Northern Affairs Canada summarizing the conceptual design of remedial measures to mitigate the hazards associated with a breach of the waste rock dump. Mitigation of the tailings piles was not covered under the scope of this assignment (UMA, 2002). The designs were based on the most recent (1999) movement monitoring results that suggested horizontal movement rates had reduced significantly from those observed prior to 1986 with average movement rates in the order of 10 cm/yr. Over the same period, vertical movement (settlement) rates remained about the same as observed in 1986, or about twice the rate of horizontal movement. Along the creek channel however, channel closure sections showed significantly less settlement, possibly as a result of the waste rock rising up along the north valley slope as the waste rock advanced.

Using the pre-failure dump geometry, slope stability analyses were carried out to investigate the strength and groundwater parameters necessary to cause an initial foundation failure of the waste rock dump and the operating strengths necessary to satisfy a factor of safety (FS) of 1.0 for the existing geometry. A FS of unity (FS=1.0) assumes that the forces acting to stabilize the waste rock (resisting forces) are equal to those responsible for the movement and the dump (driving forces). The analysis determined that a combination of very low shear strengths and high pore water pressures were required to achieve a FS of 1.0. It was concluded that unique geologic conditions, in particular a very weak foundation layer were responsible for the continued movements of the waste rock. It was also concluded that almost certainly, disturbance of the

thermal regime, in particular thawing of the permafrost resulting from seepage water from Hudgeon Lake was a contributing factor.

Based on the monitoring results, remedial measures were evaluated falling into one of three categories:

1. Remove a sufficient volume of waste rock from the valley to completely drain Hudgeon Lake and restore natural creek drainage,
2. Stabilize the waste rock dump and continue to convey creek flow over the waste rock dump along the same or an alternate alignment, or,
3. Leave as is and convey creek flow around the waste rock dump.

It was determined that significant capital costs were associated with these options and additional movement monitoring was recommended for 2001 to determine if movement rates were sufficiently small to reduce the scale of construction works to stabilize only the creek channel over the waste rock dump. Several recommendations were provided as follows:

- Continue monitoring in 2001 and perhaps beyond,
- Develop a plan for short term remedial measures at the Hudgeon Lake outlet to address the risk associated with a breach,
- Select a preferred long term remedial alternative and proceed with the necessary field investigations, functional design and detailed design.

5.7 2001 Monitoring

Subsequent to preparation of the Conceptual Design Report, waste rock movement monitoring and a detailed survey of the Hudgeon Lake outlet were carried out by UMA in June 2001. Over the two-year period from July 1999 to June 2001, annual horizontal movements ranging from 1 to 11 cm were observed, or an average annual rate of 7 cm. Over the same time period, the average rate of vertical settlement appeared to be in the order of 7 cm. These movements confirmed previous observations that waste rock pile movements were small (in comparison to movements prior to 1986) and perhaps decreasing with time. The movements were interpreted as small constant strain rates or strain rates that are decreasing with time, and as such are referred to as creep movements (as compared with the large movements observed prior to 1986). There were no signs to indicate strain rates were increasing, observations that would be expected if large movements of the waste rock were imminent. An example of the monitoring results is shown on Figure 10.

It was considered likely that these creep movements would continue at similar strain rates for many more years, and in particular, the horizontal movements may be susceptible to channel erosion (i.e. down cutting) along the north edge of the waste rock. Based on the observed waste rock movements and the comparatively lower capital costs, channel stabilization was selected as the preferred remedial option to address the hazards associated with a breach of the waste rock at the Hudgeon Lake outlet and to reduce the chronic erosion of waste rock material. Providing that channel stabilization measures could be constructed to accommodate anticipated creep movements, waste rock stabilization was not considered necessary in the short term, in particular given the possibility of further reductions in these movements. With

this in mind, it was decided that the need for waste rock stabilization could be evaluated once the channel stabilization measures were constructed and additional monitoring data became available. Because the channel stabilization works would involve partial infilling of the existing channel, it was considered possible that the observed horizontal creep movements may be reduced or possibly halted as a result of the channel stabilization work.

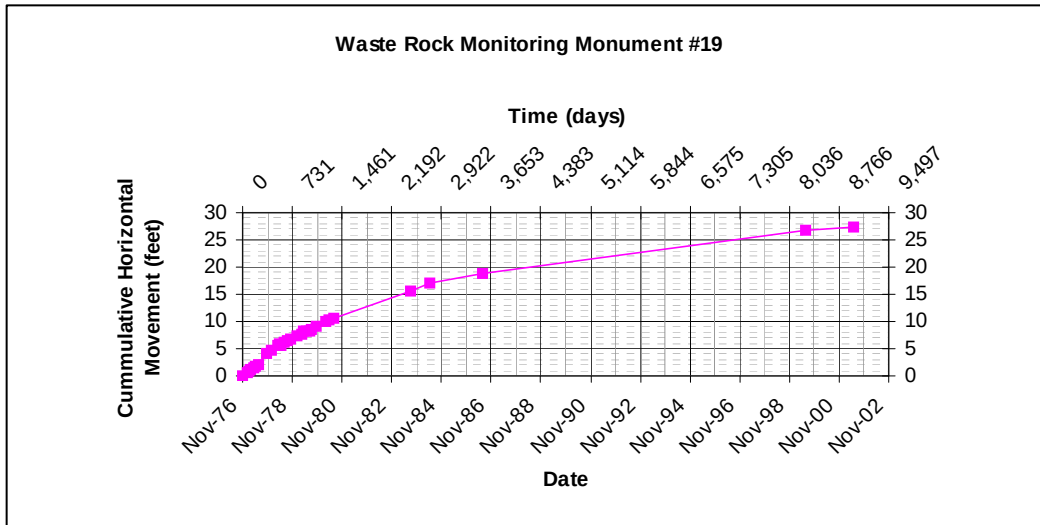


Figure 10 Example of Movement Monitoring Data

Given the possibility of conditions worsening at the outlet before the channel could be stabilized, it was recommended that the stabilization work be staged to allow the most immediate concern (the condition of the outlet) to be addressed before the overall stabilization works was completed. It was recognized that while this strategy would allow mitigation of the catastrophic breach potential, it would not significantly reduce the chronic erosion that would continue to occur downstream of the stabilized section. It was pointed out however, that the stabilization work at the outlet could be designed as a component of the overall channel stabilization measures.

5.8 Environmental Liability Report

A report summarizing the environmental liabilities associated with the former Clinton Creek Asbestos Mine was prepared for INAC by UMA in June of 2003. For the purposes of this report, environmental liability was considered to be the costs associated with the implementation of remedial measures to mitigate the risks associated with a catastrophic breach of the waste rock dump and tailings pile and the environmental concerns from chronic erosion and redistribution of waste rock and tailings downstream of the mine site. The Environmental Liability Report looked more closely at channel hydraulics along Clinton Creek and Wolverine Creek to determine appropriate drainage areas and estimated discharges from these areas (UMA, 2003).

5.8.1 Waste Rock Dump/Clinton Creek Channel

Channel stabilization works consisting of gabion structures were recommended over rigid structures (e.g. concrete) because of their flexibility that allows them to undergo deformation while remaining structurally sound, an important consideration given the observed creep movements of the waste rock. The proposed design was intended to reduce erosion of the creek channel by flattening the channel grade and lowering the velocity of the water such that it can no longer scour or erode the bed of the creek channel. Channel grade flattening would be achieved by partially infilling the channel and constructing a series of gabion drop structures. Between drop structures, the channel would be lined with granular material of sufficient size to resist the anticipated flow velocities. Channel velocities would be maintained within this range by controlling the channel geometry and grade by adjusting the number, height and location of the drop structures and the channel section would be set to the required width and depth to pass the expected creek flows. The configuration of the drop structures for the first 150m of channel stabilization is illustrated on Drawing 02.

5.8.2 Tailings Pile/Wolverine Creek Channel

The assessment of feasible remedial measures at the tailings pile was hampered by the fact no movement monitoring data had been obtained since 1986. Annual inspections and reconnaissance trips did however confirm that downslope movements of the north and south tailings lobes continued to occur, possibly at rates in the order of 5 m per year. These movements were believed to be due, at least in part, to the continued erosion of tailings from the toe of the north and south lobes by Wolverine Creek. The tailings continued to erode and be transported downstream by Wolverine Creek almost as quickly as the tailings lobes advanced into the valley bottom. Although a comparison of recent and historical aerial photography suggested there was little to no lateral spreading of the tailings within the failed area, it was considered likely that some mounding of the tailings was occurring (personal communication, M. Stepanek).

To investigate the feasibility of remedial options, slope stability analysis was carried out for the north and south lobes using representative cross-sections based on historical information contained in previous reports and the 1999 aerial photography and digital mapping. A back analysis was then carried out to determine the operating strengths and piezometric conditions necessary to achieve a factor of safety (FS) equal to unity ($FS=1.0$), a value representative of conditions where movements are imminent or are occurring. The analysis indicated that a combination of very low (residual) shear strengths and high pore-water pressures in the overburden material are required to achieve a FS of unity. This observation provided further evidence that unique geological conditions, in particular a shallow weak layer within the overburden, were responsible for continued movement of the tailings pile. Disturbance of the thermal regime, in particular thawing of the permafrost resulting from the placement of tailings over the valley slope was believed to be a contributing factor.

Remediation strategies that could accommodate the on-going down slope movements of the tailings lobes or include measures to stabilize the tailings were evaluated. These remedial strategies broadly fell into one of three categories:

1. Remove a sufficient volume of tailings from the valley and valley side slopes to completely drain the water impounded by the tailings and restore natural creek drainage,

2. Stabilize the tailings piles and convey water over the tailings in a stabilized channel or,
3. Convey water around the tailings via a tunnel.

Each of these alternatives required that the tailings be handled with earth moving equipment resulting in air-borne (fugitive) asbestos dust particles. It was anticipated that these effects could be confined to the construction period and for a short time after and that a crust would re-develop following construction of remedial measures.

5.9 2002 Site Work

5.9.1 Stage I Creek Channel Stabilization

In 2002, as decision was reached by INAC to begin stabilization measures at the Hudgeon Lake outlet. Given the possibility of conditions worsening at the outlet before a practicable length of stabilization repairs could be implemented, the work was to be staged to allow the most immediate concern (the condition of the outlet) to be addressed first by installing four gabion drop structures within the first 150 m of the channel downstream of the outlet. In the fall of 2002, the first stage of work began (Stage 1 Construction) to construct the first two drop structures. Due to the impending winter season however, only the first drop structure (Drop Structure #1) was completed (UMA, 2003a).

Construction was undertaken by Hän Construction Ltd. from Dawson City, Yukon. Hän Construction is owned by Chief Isaac Inc., which is a business unit of the Tr'ondëk Hwëch'in First Nation. The work was carried out under a contribution agreement between Indian and Northern Affairs Canada and the Tr'ondëk Hwëch'in First Nation. Site supervision was provided by UMA and INAC. Due to the potential for airborne asbestos fibres to be present during construction, a Health and Safety Plan was developed to minimize the exposure of the people working on site to airborne asbestos fibres until the first test results from air quality samples were available. The test results indicated that the level of airborne asbestos fibres were well below the allowable limit of 0.5 fibres per ml for an 8 hour exposure period. A Letter of Advice was provided by the Department of Fisheries and Oceans (DFO) for the work.

5.10 2003 Site Work

5.10.1 Stage II Creek Channel Stabilization

The 2003 site work was completed for the Government of Yukon, Energy Mines and Resources who had taken over responsibility for the Clinton Creek mine following the devolution process between the Federal Government and the Yukon Territorial Government. The original design for Stage II included a total of six drop structures (including Drop Structure #1) and the intent of the 2003 site work was to complete all of the remaining channel stabilization works in that season (UMA, 2003b). A pre-construction meeting was held in late May 2003 to discuss the work with the Contractor (Hän Construction Ltd.), the Government of Yukon, the Department of Fisheries and Oceans and UMA. Upon further investigation of channel conditions in early August, UMA recommended that the last two drop structures be eliminated from the plan. Drop Structure #2 was constructed and site preparation for the remaining two structures was completed by the end of August

2003. Due to inclement weather conditions in September, construction of Drop Structure #'s 3 and 4 was deferred until 2004. Air monitoring results from 2003 yielded similar results obtained in 2002 (fibre levels below the permissible exposure limits). The completed Stage II channel stabilization works are shown on Figure 11.



Figure 11 Completed Stage I and II Channel Stabilization Works (2003)

5.10.2 Hazard Assessment

Previous investigations at the mine site had focussed on the stability of the waste rock and tailings piles and the potential for development of a catastrophic breach of landslide dams, in particular at the Hudgeon Lake outlet. A separate program was carried out in the fall of 2003 to identify and classify human health and safety hazards at the mine site and provide recommendations for potential corrective (i.e. risk mitigation) measures. While no attempt was made to quantify or measure the associated risks, the hazards were evaluated in a qualitative manner to determine their classification and develop alternatives for hazard elimination and/or risk reduction (UMA, 2004).

The hazard identification field program was completed in two stages. The first stage involved identifying physical hazards, monitoring of waste rock and tailings pile movements and limited air sampling carried out

during the field activities. The second stage was undertaken to further understand the potential human health and ecological hazards at the mine site related to water quality issues and airborne asbestos fibres. Whereas any conclusions about possible human health risks from metals/metalloids were considered to be strongly dependent on various assumptions about the extent of human exposures and contaminant viability, imminent physical hazards at the site provided a much more clear-cut case of possible human health risks. There were a number of major physical features at the Clinton Creek Mine site that posed potential risks to people and the environment. Some of these included unstable waste rock dumps, tailings pile and high open pit walls, partially demolished structures and other mine equipment.

Stage 1 - Hazard Identification, Surveys and Air Monitoring

A reconnaissance was conducted in August 2003 to identify potential hazards in areas where significant activity took place during operation of the mine or areas that were impacted by such activity. These included the tailings pile, the Wolverine Creek channel downstream of the tailings pile, the two waste rock dumps, the three open pits, the crusher building, the mill site and the ammonium nitrate/fuel oil (ANFO) storage facility where explosives were stored. An additional site reconnaissance was conducted in September to further evaluate the hazards associated with airborne asbestos fibres and develop a program (Stage 2) for water sampling and additional air sampling. The classification of hazards was intended to provide an intuitive means to assess the significance of the hazard and the need for measures to either eliminate the hazard or reduce the associated risks. The hazard classifications were also useful in determining priorities for the mitigation work which was expected to take longer than one construction season to complete. Significant mine site features for which hazards identified included:

- Waste rock dump movements (breach) and asbestos fibres within the waste rock,
- Unstable open pit walls,
- Tailings pile movements (breach) and asbestos fibres in tailings,
- Crusher building,
- Tramway towers,
- Mill site (foundations, structures, conveyor tunnels, pits, asbestos fibres etc.),
- Ammonium nitrate fuel ordinance (ANFO) storage facility, and
- Miscellaneous features including structures and derelict equipment.

Each hazard was classified based on the severity of the potential outcome due to exposure to that hazard (from a health and safety perspective). A four level classification system was used (negligible, low, moderate or high) based on the associated consequences of exposure to the physical hazard. Hazards associated with asbestos were not classified at that time because additional work was underway to assess the risks associated with airborne asbestos fibres.

Underhill Geomatics from Whitehorse, Yukon completed a GPS survey of movement monitoring points on the Clinton Creek waste rock dump and the Wolverine Creek tailings pile. Pit slope monitoring was reactivated using four previously installed movement monitors. A profile survey of the Wolverine Creek channel was completed and channel closure monitoring points were established on both sides of the drop structure constructed in 2002 to measure deformation of the structure from waste rock movements. Beginning in 2003, the survey method was switched from total station to GPS and previous surveys completed in the mine grid co-ordinate system were transformed to the UTM NAD 83 (Zone 7) co-ordinate system.

Based on the survey monitoring carried out in 1999, 2001 and 2003, the average rate of horizontal waste rock movements was estimated to be in the order of about 6 cm/yr. While this rate of movement of the waste rock pile was considered small compared to previous (historical) observations, it was concluded that should movements continue at this rate (e.g. 5 cm/year over 10 years = 50 cm) the integrity of the gabion drop structures could be compromised in the foreseeable future. The monitoring points on either side of the gabion drop structures were therefore installed to determine how much of the waste rock movement is reflected in deformation of the gabion drop structures. There was insufficient data collected to that point in time to reliably determine movement rates of the Porcupine Pit wall and tailings piles.

Eight air samples were collected during the first stage of the site investigation work. These samples were analyzed to determine the concentration of asbestos fibres. The test results indicated that exposure to asbestos fibres was likely to occur during any activity in areas of the mine site where the ground surface is covered with asbestos. Although airborne fibre levels measured indicated concentrations were below the Yukon 8-hour permissible exposure limit of 0.5 fibres/ml, it was expected that exposures would be higher during construction, demolition or certain types of recreational activity than those measured in this study, particularly under dry site conditions.

Stage 2 – Screening level Risk Assessment

In 2003, SENES Consultants Limited conducted a screening environmental risk assessment (SLRA) of the former Clinton Creek Mine site, as part of a series of Screening Level Risk Assessments of eleven mine sites and thirteen former military sites in northern Canada on behalf of INAC (SENES, 2003). The SENES work included a statistical assessment of the 1998 field data from the 1999 RRU report to determine appropriate concentrations to use in the assessment. Asbestos in air concentrations measured in 2003 were also used in the assessment. The results from this program are discussed in Section 6.6.3 of this report.

5.11 2004 Site Work

5.11.1 Stage III Creek Channel Stabilization

The final portion of the channel stabilization works were completed in 2004 by Hän Construction Ltd. from Dawson City, Yukon (UMA, 2005). Work included the construction of Drop structure #'s 3 and 4 and associated channel shaping and restoration within the work area. The final channel stabilization works are illustrated on Figures 12 and 13.



Figure 12 Construction of DS #4 (2004)



Figure 13 Completed Stabilization Works (2004)

5.11.2 2004 Hazard Mitigation

The Government of Yukon undertook a hazard mitigation program in the summer of 2004 to address the hazards identified in UMA's Hazard Assessment Report (UMA 2004). In general, the work program involved demolition of most of the structures on the site and site re-grading work to block access to some areas of the mine site, cover areas having significant concentrations of asbestos fibres and backfill demolished concrete structures. The work was completed under a contract between the Government of Yukon – Energy, Mines and Resources (GY-EMR) and the General Contractor, Hän Construction Ltd.

Demolition Work

The demolition work was largely undertaken by Visco Demolition Contractors Ltd. of Edmonton, Alberta, with some assistance from the General Contractor (Hän Construction Ltd.). With the exception of concrete rubble, the demolition materials (e.g. steel, tin, machinery) were stockpiled just north of the former crusher building. Significant demolition work included the former crusher building, tram towers, tram terminus building, concrete buildings from the former office building at the Mill Site, utilidor access structures and conveyor tunnels at the Mill Site, water storage and fuel storage tanks at the Mill Site, and the ANFO Storage Facility. The large, heavily reinforced concrete foundations at the former mill site and crusher building and Tram Tower #3 were left in-place because the degree of difficulty in demolishing these structures and their respective negligible to low hazard classification. The access ladder rungs on Tram Tower #3 were cut-off to prevent climbing.

Earthworks



Figure 14 Crusher Building Demolition (2004)



Figure 15 Regraded Mill Site (2005)

The balance of the hazard mitigation activities completed in 2004 was undertaken by Hän Construction Ltd. In general the work involved regrading some areas of the mine site having visible concentrations of asbestos fibres at ground surface, backfilling pits, shafts and concrete rubble from building demolition, relocating miscellaneous pieces of wood and steel to the demolition material stockpile, cutting off exposed reinforcing steel around the Mill Site area and blocking vehicle access to various areas of the mine site.

5.11.3 2004 Screening Level Risk Assessment

A Screening Level Risk Assessment (SLRA) was carried out by UMA in 2004 to provide an update to the evaluation of human health hazards and risks at the former asbestos mine site, based on site conditions as of late 2004. It included an update of priorities in light of physical hazards at the site, as well as a simple quantitative evaluation of human health risks specifically focussed around the issue of inhalation-type risks from airborne chrysotile asbestos fibres.

Air Monitoring

The air monitoring program was undertaken in two stages, in late July and late August/early September while the Stage III channel stabilization work was underway. The results of air monitoring conducted by Hän Construction Ltd. during the demolition work was not included in the SLRA as they were not considered to be representative of ambient conditions. Sixty air samples (50 area and 10 personal samples) were collected. The area samples represented ambient air conditions and the personal samples represented conditions while traversing various areas of the mine site by foot, all-terrain vehicle (ATV) and automobile. Each area sample was collected by setting up an air sampling pump at one location for the duration of the sampling period. Personal samples were worn by people moving around the site by automobile, ATV, walking or in one case, while operating a bulldozer. Typically, one personal sample was collected while setting out and retrieving the pumps used to collect up to six area samples at various locations across the mine site. A weather station with a data logger was also setup at the Former Mill Site to capture site specific data on precipitation, temperature, dew point temperature, relative humidity, wind speed and wind direction. The results of this program are discussed in Section 6.6.3 of this report.

5.11.4 Surveys

The results of site surveys from 2004 were included in the SLRA. Surveys were completed by Underhill Geomatics include movement monitoring at the Clinton Creek waste rock dump, Porcupine Creek open pit and tailings pile. A centerline profile along Clinton Creek was also surveyed in 2004.

Waste Rock Dump, Open Pit Wall and Tailings Pile Movement Monitoring

In 2003, the movement monitoring program at the waste rock dump was revised from seven monitoring points to forty-two (UMA 2004). The additional monitoring points consisted of seven new monitoring points, four survey control points established during the 1999 and 2001 surveys and existing standpipe piezometers, channel closure pins, old waste rock monitor points and four pit slope monitor points. The main objective was to provide monitoring points across the portion of the waste rock dump where movements could impact the gabion drop structures. Many of the new monitoring points were located along the toe of the waste rock dump, which also forms the south bank of the creek. The waste rock movement monitors were categorized according to location on the waste rock dump that is, the lower slope monitors being located below elevation 420 m, the mid-slope monitors located between elevation 420 m and 450 m and the upper slope monitors located above elevation 450 m.

The results from 2004 confirmed that annual rates of horizontal waste rock movements had significantly decreased since monitoring first began in 1978. Results from 1999 to 2004 showed horizontal movements ranging from 1 to 13 cm/yr with an average of 5 cm/yr in 2004. The monitoring results for the Porcupine Pit slope monitors suggested that there is little movement of the pit walls at the location of the monitors. It was pointed out however that the unstable areas of the open pit are quite obvious upon visual inspection and in general, the south west and south east corners of the pit are the most unstable and susceptible to large and sudden failures.

Clinton Creek Channel Profile

The Clinton Creek channel profile along the toe of the waste rock dump was surveyed to assess rates of erosion and down cutting of the channel. Figure 16 shows the creek profiles surveyed between 1983 and 2004. The surveys from 1999 and 2001 were completed before the channel stabilization works were undertaken. The 2004 survey includes the gabion drop structures in the creek profile. The survey was considered sufficient to identify changes in channel bottom elevation in the order of tenths of a metre. Repeatability in surveyed elevations is impacted by the location of survey shots, shifts in the creek thalweg due to sloughing of the waste rock pile and valley slope and erosion of the channel. A comparison of the creek profiles suggested that a significant amount of down-cutting occurred sometime between 1986 and 1999. The 1997 flood event that washed out the last remnants of the boulder drop structure at Station 0+140 m was likely responsible for the majority of erosion seen between the 1986 and 1999 creek profiles. The surveys in 1999, 2001 and 2004 suggested that minimal erosion had occurred in recent years.

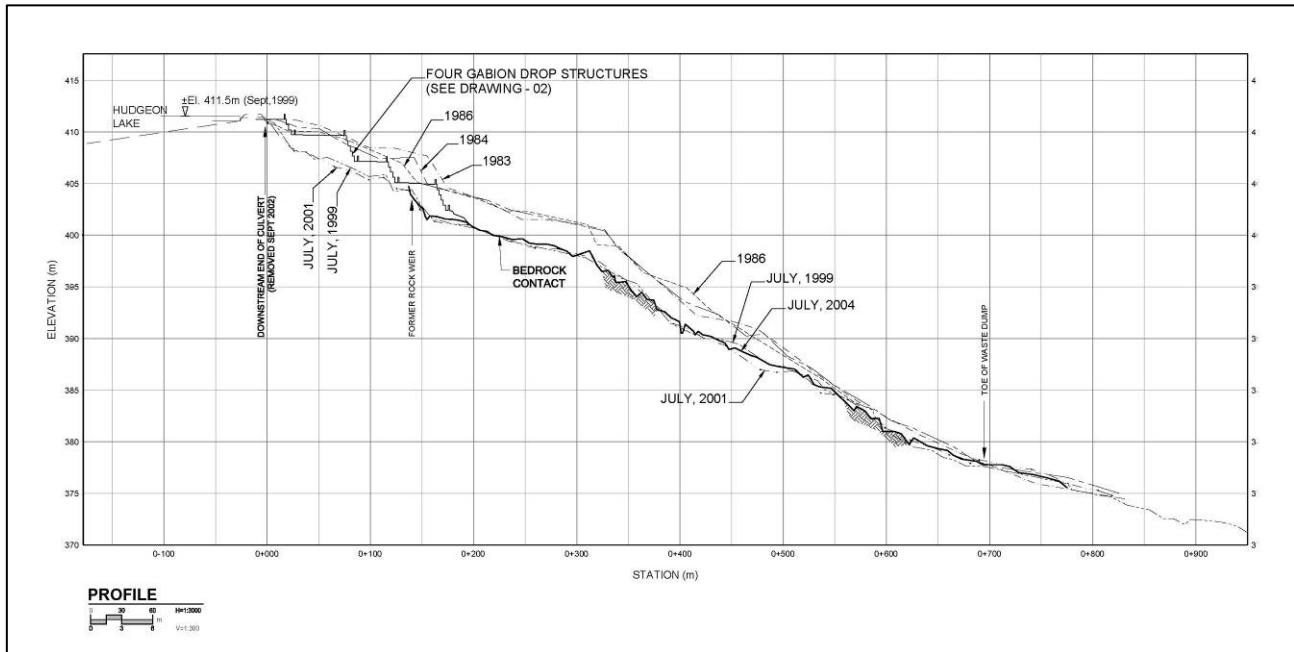


Figure 16 Clinton Creek Channel Profile

Tailings Piles

Based on the monitoring period from August 2003 to July 2004, it was concluded that the tailings pile was still moving but likely at rates less than originally thought. When the monitoring program was reinstated in 2003, twenty original monitor locations were located and ten new points were added to provide monitoring data at key points on the tailings pile, particularly at the toe along Wolverine Creek. The points were grouped according to their location on the upper, mid and lower slope areas. The monitors on the upper slope are located above elevation 530 m, the mid slope monitors are located between elevation 425 and 530 m and the lower slope monitors are located below elevation 425 m. A series of alignment pins were also placed in a straight line across the toe of the north lobe and south lobe to provide a means to visually check for movements.

When the original monitoring program ended in 1984 the north and south lobes were moving at rates up to 25 m and 7 m per year, respectively (UMA 2003). The higher movement rates for the north lobe was a consequence of the tailings having not yet reached the valley bottom and therefore had minimal toe support to resist the movements. The horizontal movement rates calculated from the 2003 and 2004 monitoring data showed that the movements were considerably less than previously measured and speculated on in previous reports (UMA 1999). The south lobe was observed to be the most active, particularly in the mid slope area which moved horizontally about 0.9 m (3 ft) between August 2003 and July 2004. The lower slope area appeared to be moving north east and south east, possibly as a result of lateral spreading and some mounding was evident at the toe area. The upper slope was moving relatively slowly at about 0.24 m per year. Movements of the north lobe were small in comparison to the south lobe with the largest magnitudes of 20 to 60 cm/yr occurring along the south and east edges of the mid-slope area. In general, less than 3 cm of movement was seen in many of the remaining monitors which is about the accuracy of the survey method used.

Although the movement rates appeared to be significantly less than previously observed, additional monitoring was recommended to confirm the movement rates observed between 2003 and 2004. Based on the recent movement rates measured and the height and length of tailings along Wolverine creek, the volume of tailings eroded annually was estimated to be in the order of 1,500 m³ per year compared to previous estimates of 7,500 to 15,000 m³/yr (UMA, 2000).

5.11.5 Seeding Trials

In September 2004, tree planting and grass seeding trials were undertaken at various areas of the former mine site including willow shoots and small coniferous trees planted in the Clinton Creek channel between the drop structures. The Government of Yukon was advised to remove this vegetation along the channel since it had been designed with a very flat gradient to reduce flow velocities and did not account for hydraulic losses resulting from trees in the channel cross-section.

5.12 2005 Site Work

5.12.1 Inspection & Monitoring

An inspection was carried out in May 2005 after the spring freshet to evaluate the condition of the creek stabilization repairs on Clinton Creek that had been completed the previous summer (UMA, 2006a). While on site, a photographic record of the rock lined channel on Wolverine Creek was completed and the Wolverine Creek tailings pile was also visited to aid in interpreting the movement monitoring results from 2004.

Clinton Creek Channel

The purpose of the inspection was to observe the condition of the creek channel stabilization works, which were completed in September 2004 (UMA 2005), and identify any maintenance requirements. Of particular interest for the 2005 inspection was determining the condition of the transition between the last drop structure and the unstabilized creek channel. Measurements across the gabion drop structures indicated that 1 to 12 cm of lateral movements may have occurred, which was comparable to the magnitude of the waste rock movements. Although the drop structures were not showing any signs of distress, continued monitoring was recommended to assess long term impacts associated with continued waste rock movements.

Flow over the gabions at the time of the inspection prevented a detailed inspection of the gabion baskets. Subsequent inspections by the Government of Yukon at lower flows revealed that some gabion fill had been washed out of the baskets forming the floor of Drop Structure #'s 3 and 4, constructed in 2004. Recommendations were provided to open and top off the baskets with 100 to 200 mm diameter fill which had been stockpiled on site. No loss of material was observed in Drop Structure #'s 1 and 2 which had been similarly repaired in the summer after their construction (2002 and 2003 respectively). Minor channel erosion was evident between Drop Structure #'s 2 & 3 and 3 & 4 where the channel fill was mainly argillite waste rock. Similar channel erosion was not evident between Drop Structure #'s 1 and 2 where cobbles and boulders were used to line the channel. Given the veneer of larger particles remaining on the slopes and the

flat channel grade (approximately 0.1 percent) it was expected that the existing channel armouring between the drop structures would be sufficient. It was recommended that in the event that erosion continued, some of the remaining gabion fill be used for armouring the channel between Drop Structure #'s 2 & 3 and 3 & 4.

The channel transition downstream of Drop Structure 4 showed some signs of erosion on the north side of the channel and shifting of some of the large boulders. It had been anticipated that this might occur and that some maintenance work would be required in 2005 to adjust and infill the armouring after the first spring freshet. Minimal, if any, erosion was observed on the right hand side of the channel. It was recommended that additional armouring be placed on the left hand side of the channel transition downstream of Drop Structure #4, and all non-grass vegetation located within the channel cross-section be removed.

Wolverine Creek Channel

The rock lined channel originally constructed in 1978 was functional. Although trees had grown in and around the channel that may have been affecting the hydraulic capacity, there was no evidence that flow had overtopped the banks. No significant channel blockages were identified although there were some signs of sedimentation taking place and some shifting of boulders that form the rock lined weirs. No immediate maintenance work was identified.

Tailings Piles

The lower portion of the tailings pile was inspected to further evaluate the movement trends from the 2003 and 2004 tailings pile monitoring surveys. It appeared that the tailings on the South Lobe may be spreading laterally at the valley bottom and not moving directly east across the valley. It was recommended that 11 new monitoring points be established during the 2005 movement monitoring survey to aid in determining movement patterns.

5.12.2 Maintenance Activities

The maintenance work recommended was undertaken by the Government of Yukon (through local contractors) in the summer and fall of 2005.

5.13 2006 Site Work

5.13.1 Hazard Mitigation and Clean-up Activities

Stockpiled demolition waste was disposed of in trenches dug within the waste rock pile and covered with waste rock material. This work was done under a Commercial Dump Permit issued by the Yukon Department of Environment. Occupation Health and Safety regulations regarding asbestos control and decontamination were followed. A ditch and berm was dug around portions of the open pits and warning signs were installed around the perimeters as a public safety measure. Some additional seeding trials were implemented on the waste rock and tailings.

5.13.2 Long term Performance Monitoring Program

A Long Term Monitoring Program was developed for the mine site to provide information on the performance of physical mine site features (i.e. waste rock dump, creek stabilization works, Wolverine Creek channel and the tailings pile) and an action plan from which decisions could be made to undertake additional work at the site where required to ensure the long term stability of these features (UMA, 2006). The monitoring program recommended monitoring frequencies and criteria (trigger levels) to determine when action is required to undertake repairs to maintain adequate long term performance of the Clinton Creek waste rock dump, the channel stabilization works constructed at the Hudgeon Lake outlet and the Wolverine Creek tailings pile and rock-lined channel. Details of the recommendations from this report are summarized as follows:

Clinton Creek Channel Stabilization Drop Structures

It was concluded that the trapezoidal cross-section of the gabion drop structures could withstand significant lateral deformation without any significant increase in flow depth. It was recommended that planning of remedial works of the gabion structures, including establishing timelines for construction, begin when the monitoring data shows that either the flow depth (i.e. water surface) at the design discharge is within 0.2 m of the top edge of the gabions, the side slope(s) reach 2H:1V, the drop structure measurements are 0.5 m less than the baseline readings and/or if the top width determined from the surveyed cross-sections of the drop structures decreases by a similar amount. It was recommended that the remedial work be undertaken within one year at which time, the feasibility/requirement for waste rock pile stabilization should also be revisited.

Clinton Creek Channel Degradation

Degradation of the channel downstream of the last drop structure was considered to be of less consequence to stability of the channel stabilization works but would be expected to trigger localized slope failures and possibly increase the rate of observed waste rock movements. The July 2004 survey would serve as the baseline to which future surveys could be compared to determine the rate and magnitude of degradation. Maintenance work was recommended when creek channel surveys indicated 0.5 m of down-cutting immediately downstream of the fourth drop structure. Farther downstream, planning for channel stabilization and any requirements for waste rock stabilization was recommended when 1.5 m of channel degradation is evident along a measurable stretch of the channel i.e. localized channel down cutting may not trigger the need for repairs.

Tailings Piles and Wolverine Creek Channel

It was recommended that planning for tailings pile stabilization be initiated if the annual movement rates from any one monitoring event increase by an order of magnitude or if the annual rates of movement from two consecutive monitoring events show progressively increasing rates of movement. It was recommended that planning for channel stabilization works upstream of rock lined portion of the Wolverine Creek channel be initiated when 1 m of channel degradation is evident along a measurable section of the channel and when 0.5 m of channel degradation is evident along a measurable section of the rock lined channel section.

Porcupine Creek Pit

The Porcupine Pit was not specifically included in the long term performance monitoring program in so far as trigger levels are concerned.

5.13.3 Site Inspections and Surveys

Site inspections and surveys were completed in July of 2006 based on the recommendations for the long term performance monitoring program for the site (UMA, 2007).

Waste Rock Dump and Clinton Creek Channel

Horizontal (closure) movements rates ranging from 5 to 12 cm/yr were measured at the gabion structures compared to movement rates of the waste rock dump ranging from 1 to 7 cm. The difference in these rates suggested that the structures were still undergoing some post-construction adjustments in addition to the movement attributable to the waste rock movements. It was also determined that the flow depth was within 0.2 m of the top edge of the first drop structure (#1) and remedial repairs were recommended to deal with this freeboard deficiency. Channel downcutting of the Clinton Creek channel of 0.2 to 0.3 m was measured immediately downstream of the boulder transition section downstream of the last drop structure. Although this measurement was significant enough to trigger planning for channel revetment work, the affected stretch was short (10 m) and appeared to be well armoured. A recommendation was therefore made to re-inspect this stretch in 2007 to determine if this action would be necessary. Only minor erosion and some deposition were observed for the remainder of the creek channel through the waste rock dump.

Porcupine Creek Pit

Movement rates of about 1 cm/yr were observed at the four movement monitors installed on the east pit wall. No inspections of the unstable areas of the pit, e.g. the west wall, were carried out.

Tailings Piles and Wolverine Creek Channel

Average horizontal movement rates of the upper, mid, and lower portions of the south lobe of 10, 65 and 35 cm/yr were measured. Average horizontal movements of the north lobe were 6, 13 and 9 cm/yr for the upper, mid and lower portions of the north lobe respectively. In both cases, the rates were less than had been measured over the previous monitoring period from 2004 to 2005, likely due to increased mounding of tailings in the toe area. Since none of the trigger levels were reached, no action was deemed necessary. The rock lined section of the Wolverine Creek channel was in good condition. No conclusions could be drawn with respect to channel erosion through the tailings due to a survey discrepancy that could not be resolved.

5.14 2007 Site Work

5.14.1 Site Inspections and Surveys

Site inspections and surveys were completed in July of 2007 based on the recommendations for the long term performance monitoring program of the site (UMA, 2008).

Waste Rock Dump and Clinton Creek Channel

Inspections showed that the gabion drop structures were performing well with grass and other vegetation becoming established around the channel (Figure 17). An erosion gully was noted on the north side of the access road. The results from the horizontal measurements taken across each structure and the movement monitors located at the four corners of each drop structure confirmed that the width of the gabion drop structures was decreasing with time at a current rate (2006-2007) of approximately 10 cm/yr. The largest movement to that date (July 2007) was 27 cm at Drop Structure #3. Other than the previous observation regarding a freeboard deficiency at Drop Structure #1, no deformations were observed that would compromise the drop structures ability to pass the expected design flow from Hudgeon Lake i.e. no trigger levels were reached. The rate of change of the drop structure width was of the same order of magnitude as the waste rock movement monitors located directly south of the stabilized creek channel. No significant channel erosion along Clinton Creek was observed, including the stretch downstream of the boulder transition where 0.2 to 0.3 m was measured in the previous year.

Several recommendations were made for maintenance work in the vicinity of the stabilized channel section including the addition of gabion baskets to the top row of Drop Structure #1 and the removal of one cell (1 m x 1 m x 0.5 m) from the drawdown weir to reduce the impact from woody debris accumulating at the Hudgeon Lake outlet. Other maintenance work included patching a hole in the basket on Drop Structure #2, removing cobbles along the edge of Drop Structure #3 and topping up gabion baskets in Drop Structures #'s 2, 3, and 4. It was also recommended that all trees (mainly willows) growing within the stabilized channel section be removed and the scour holes immediately downstream of the boulder transition (downstream of Drop Structure #4) be infilled. Drainage improvements were recommended along the access road above the drop structures where gullies had formed.

Porcupine Creek Pit

No surveys or inspections of the open pit were carried out in 2007.

Tailings Piles and Wolverine Creek Channel

The rock-lined channel was observed to be stable with the channel bed well armoured by boulders and vegetation, although some of the vegetation was thought to be affecting the hydraulic capacity of the channel. There were no obvious signs that flow had overtopped the banks. At a number of locations, the right bank (when facing downstream) of the channel appeared to be higher and better armoured than the left bank. The primary concern identified with respect to the long term performance of the rock-lined channel was the potential for a bank breach resulting in the rapid erosion and down-cutting of the tailings material.

The channel profile survey planned was not completed due to the presence of bears in the area. Maintenance work recommended included the removal of an old beaver dam in Wolverine Creek at the upstream end of the south lobe and removal of tree trunks within the rock lined portion of the channel.

Recommended Future Work

Future work recommended included another round of performance monitoring in 2008 (as per the Long Term Performance Monitoring Plan), evaluation of regrading waste rock above Drop Structure #'s 3 and 4 where steeper slopes were thought to be contributing to somewhat higher movements (closure) of the structures, hydraulic modeling to estimate the risk of a breach of the rock lined section of Wolverine Creek and the surveys necessary to complete the modelling.



Figure 17 Stabilized Channel Section at Hudgeon Lake Outlet (2007)

5.15 2008 Site Work

5.15.1 Site Inspections and Surveys

Site inspections and surveys were completed in July of 2008 based on the recommendations for the long term performance monitoring program of the site (UMA, 2009).

Waste Rock Dump and Clinton Creek Channel

Survey results indicated that from 1 to 6 cm of horizontal (closure) movement occurred at the drop structures from 2007 to 2008. Over the same period, horizontal waste rock movements ranging from 0 to 6 cm occurred. Both the waste rock and drop structure movements were less than observed in the previous monitoring interval from 2006 to 2007. The waste rock movement monitoring data suggested that the western area of the waste rock dump nearest to Hudgeon Lake was moving in a westerly direction towards the lake and the main mass of the waste rock dump was moving in a northerly direction across Clinton Creek. It was concluded that overall, the waste rock was closing in on the stabilized section of the creek channel at a rate of about 5 cm/yr and the structures are deforming (closing) at a rate consistent to the waste rock movement. No trigger levels were reached.

The 2006 and 2007 surveys showed that about 0.2 to 0.3 m of channel degradation had occurred around Station 0+200 m. The subsequent work undertaken by GY restored the creek profile in this area to near the baseline level. The 2008 survey results show that the changes in the creek profile since 2006 are minor and the creek profile is well above the trigger levels shown on the drawings.

Porcupine Creek Pit

No surveys or inspections of the open pit were carried out in 2008.

Tailings Piles and Wolverine Creek Channel

The 2008 movement monitoring surveys showed that movement rates of the tailings had reduced during each of the previous three monitoring periods, likely as a result of mounding of tailings at the toe of the slide mass. In 2008, the North Lobe was observed to be moving downslope at an average rate of about 7 cm per year. The bulk of the South Lobe was moving at an average rate of about 35 cm per year with the main movements in a north easterly direction towards the pond between the lobes. The profile survey of Wolverine Creek suggested that the channel had infilled by about 1 to 1.5 m within the rock lined section. However, based on the uncertainty associated with the baseline survey, it was recommended that the interpretation of these results be deferred until after the 2008 site inspection.

5.15.2 2008 Review of Suggested Improvements to Hudgeon Lake

Observations obtained during channel stabilization works at the Hudgeon Lake outlet indicated that adult grayling occurred, at least in low numbers, within Hudgeon Lake prior to completion of outflow channel

stabilization from 2002-2004. A large number of adult grayling were also recovered from the waste rock portion of the creek channel during the fish salvage operations conducted before construction of the gabion drop structures (UMA 2003a, 2003b & 2005). It had also been documented that Clinton Creek downstream from the Hudgeon Lake outlet, during summer-time, supports not just adult graylings, but also juvenile Chinook salmon and small numbers of slimy sculpins (DFO, 2007; RRU, 1999).

White Mountain Environmental Consulting (WMEC, 2008) conducted a study during July-August, 2007, of fish presence and habitat suitability in Hudgeon Lake and upstream tributaries. The tributaries include Easter Creek, Bear Creek, Upper Clinton Creek, a tributary to Upper Clinton Creek, and an unnamed tributary near Easter Creek. Evaluations for fish utilization within the creek environments consisted of several techniques to ensure capture of all species present, including electro-fishing, deployment of minnow traps (G-traps) set at all sampling locations with a variety of baits including Chinook salmon roe, and angling with light spinning gear. Hudgeon Lake was sampled using gill nets and by beach seining, which was constrained by the large amount of submerged woody debris present.

According to WMEC, “No fish were found in any of the habitats investigated during this project during either of the sampling periods. Benthic invertebrate production was noted in all areas investigated.” The absence of fish within the watershed above the engineered control structure (i.e. the gabion drop structures) at the Hudgeon Lake outlet was thought to (might be) attributable to one or more of the following:

1. the Gabion control structures might act as a barrier to fish passage (WMEC, 2008; DFO, 2007),
2. Hudgeon Lake has been observed to be anoxic in all but its surface waters, and the low oxygen conditions during both summer and winter (under ice) are not suitable for over-wintering survival of fish,
3. Alteration of flows in the system relative to historical conditions might lead to higher than normal water temperatures during the summertime and thermal stress (DFO, 2007), and/or
4. The smaller tributaries leading into Hudgeon Lake (Easter Creek, Bear Creek, Upper Clinton Creek, a tributary to Upper Clinton Creek, and an unnamed tributary near Easter Creek) may be naturally poorly suited to fish presence based on foraging activities and/or over-wintering survival.

An assessment of measures that might counteract some of the above influences on the absence of fish usage of Hudgeon Lake and the upper reaches of Clinton Creek was undertaken by AECOM in 2008. The two measures examined were; i) partially infilling Hudgeon Lake with waste rock or ii) permanently lowering the level of Hudgeon Lake by removing the existing gabion drop structures and constructing a deeper creek channel.

Partial Lake Infilling

It was determined that conditions in Hudgeon Lake would likely not be substantially changed by covering the lake bottom with waste rock material, since such action would not alter over the longer term (i) the mass of organic matter resident within the lakebed, and annual flux of new detrital organic matter; (ii) rate of re-

oxygenation at the lake surface; or (iii) supply of sulfate in water that is available for microbial sulfate reduction (and sulfide generation).

Permanently Lowering Lake Level

With respect to lowering the level of Hudgeon Lake, it was determined that removal of the gabion drop structures could result in a lake level that is about 9 m lower than the current level and the corresponding creek channel would be in the order of 70 m wide. Unloading material from the upper portions of the waste rock pile would be required to account for the destabilizing effects of excavating a deeper creek channel at the toe of the waste rock pile. A new channel would need to be designed that provides a comparable level of erosion protection to minimize the risk of a dam breach at the lake outlet. Suitable material of sufficient volume for armouring a channel of this expanded magnitude is not readily available on the mine site.

It was also believed that lowering the lake level would potentially have a negative impact on the stability of the valley side slopes currently below the water line of the lake due to the permafrost degradation that has occurred. Staged construction over multiple years would be required to minimize channel excavation problems related to groundwater seepage and also to minimize the potential for landslides of the valley slopes below the surface of Hudgeon Lake. From a geotechnical perspective this work was not recommended because of the potential for a breach of the lake outlet to occur during construction. Furthermore, it was concluded that conditions in Hudgeon Lake would likely not be substantially improved by lowering the lake level since this would not address the root cause of current anoxic conditions; i.e., organic C supply, limited oxygen exchange at the lake surface, and presence of high sulfate levels.

Conclusions

AECOM concluded that the potential is extremely low for further increasing over-wintering survival through additional engineered solutions such as lake infilling or a permanent reduction of the level of Hudgeon Lake. With respect to Hudgeon Lake infill, at least 3 million m³ of waste rock material would likely be required to partially infill the deepest areas of the lake by about 10 m. From a geotechnical perspective the only benefit of completing this work is off-loading material from the waste rock dump which would help to stabilize the mass. In this regard, it was considered to be more cost effective to stabilize the waste rock dump by determining the amount of material that needs to be off-loaded and push material directly into Porcupine Pit. The volume of material and the unit cost of moving the material would be significantly less than that estimated for partially infilling the lake.

6. Historical Summary and Current Status

Even though considerable work was done by the former owner (Cassiar Asbestos Corporation) and subsequent Federal and Territorial agencies responsible for care and maintenance, lingering physical hazards primarily associated with the unstable waste rock dumps and tailings piles prevail at the former Clinton Creek Asbestos Mine. This section provides a brief historical summary for each area and summarizes the closure options that have been previously considered in light of the most recent (2008) performance monitoring data. The approach of continued care and maintenance (status quo) is first described for each area.

6.1 Clinton Creek Waste Rock Dump and Channel

6.1.1 Historical Summary

The Clinton Creek valley during the initial stages of waste rock disposal is shown on Figure 18. A slope failure of the waste rock dump into the Clinton Creek valley occurred during active mining in 1974 (Figure 19). The resulting landslide dam blocked natural drainage through the valley creating a 74 ha lake (Hudgeon Lake) as shown in Figures 19 to 21. It was postulated that a weak foundation material contributed to the continued horizontal displacements following the initial failure of the waste rock dump (Golder, 1978). The loss of strength was believed to be related to a number of geological conditions unique to the site including ice content, soil type and the relationship between the rate of permafrost thawing and dissipation of excess pore-water pressures. It was also considered likely that disturbance to the thermal regime, in particular thawing of permafrost beneath the dump, has resulted from filling of the upstream reservoir (Hudgeon Lake).

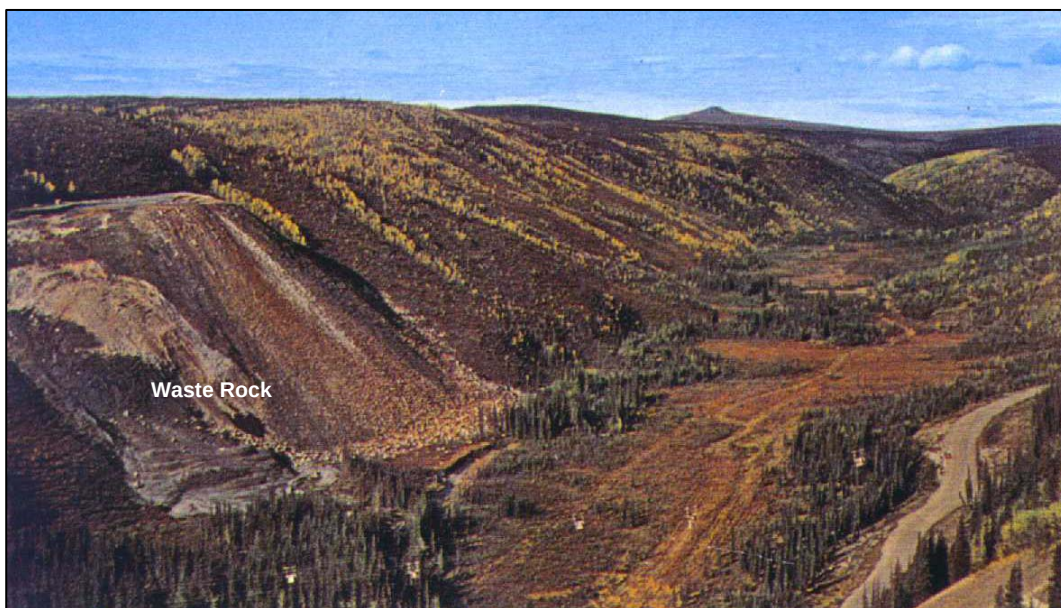


Figure 18 Clinton Creek Valley (circa 1970)

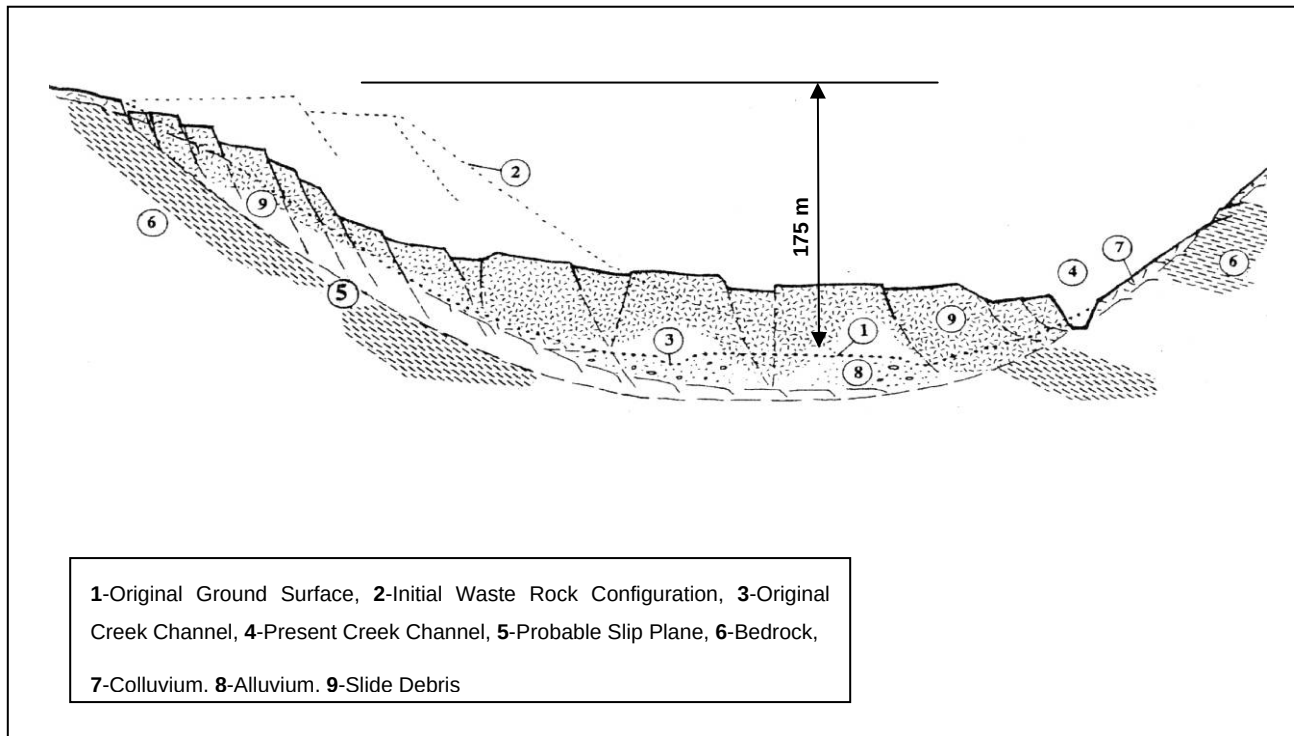


Figure 19 Channel Cross Section After Waste Rock Slide (View Upstream)
(Reference: Stepanek & McAlpine, 1992)



Figure 20 Clinton Creek Channel (1998)

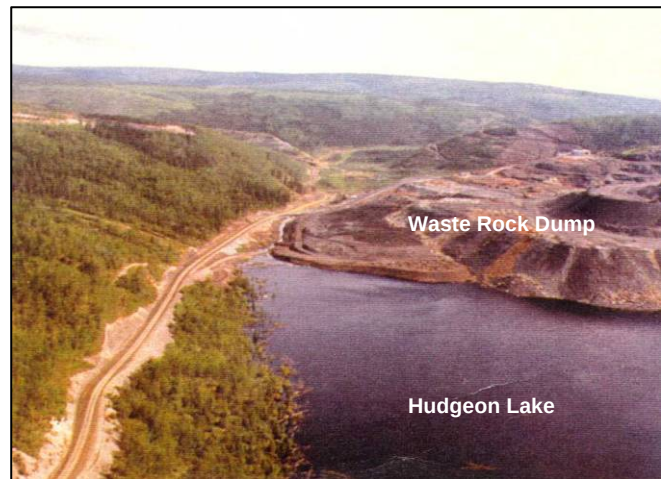


Figure 21 Clinton Creek Waste Rock Dump (1974)

As illustrated in Figure 19, a new creek channel was subsequently formed along the interface between the landslide material and north valley slope, some 25 m above the original valley bottom at the Hudgeon Lake outlet. Within the area now occupied by the waste rock dump, the creek channel was approximately 700 m long with a gradient ranging from about 3 to 6 percent compared to its natural gradient of approximately 0.08

percent. The original channel erosion protection measures constructed just downstream of the Hudgeon Lake outlet in 1981 included a series of small rock weirs, which were by-passed in the spring of 1982 (Figure 22). The erosion control works, which were constructed using large boulders recovered from the open pits, have proven to be largely unsuccessful and by 1984 had been re-constructed twice. The erosion control works re-constructed in 1984 (Figure 23) were by-passed in a significant flood event in the spring of 1997 (Figure 24). Approximately 3 m of channel erosion (i.e. down-cutting) occurred immediately downstream of the outlet between 1986 and 1999. Farther downstream, less down-cutting was evident, where the creek channel had cut into the bedrock.



Figure 22 Hudgeon Lake Outlet (1982)



Figure 23 Hudgeon Lake Outlet (1986)



Figure 24 Hudgeon Lake Outlet (1997)

Progressive erosion (i.e. down-cutting) of the Clinton Creek channel immediately downstream of and towards the Hudgeon Lake outlet increased the likelihood of the development of a full breach of the landslide dam. Figure 25 shows the channel bottom in 1986 and 1999 after the 1997 flood event when the erosion control works were effectively destroyed. It was feared that the retrogressive incising would rapidly continue and a full breach at the lake outlet could be triggered. The breach was not considered susceptible to any particular precipitation event i.e. a relatively minor flow event could trigger the failure mechanism necessary to initiate a breach. It was estimated that a full breach of the waste rock blockage at the Hudgeon Lake outlet would result in significant downstream flooding and debris flows.

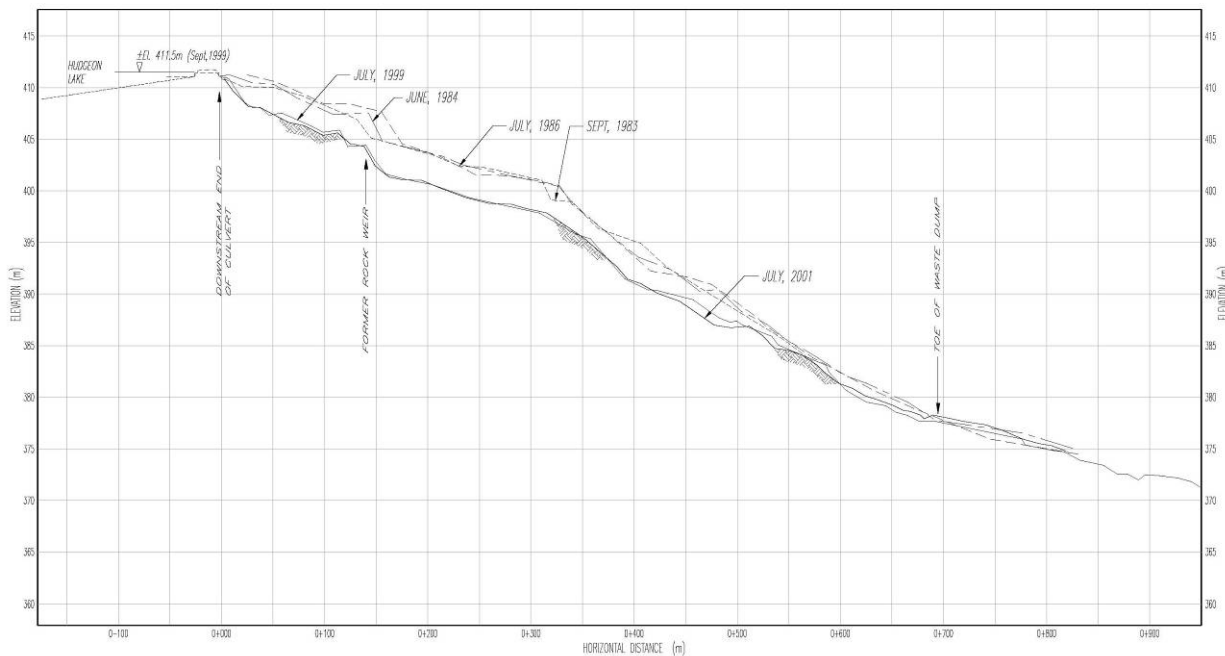


Figure 25 Clinton Creek Channel Profile

In 1999, the movement monitoring program for the Clinton Creek waste rock dump was re-established and the results confirmed observations made shortly after mine closure that the movement rates of the waste rock dump were decreasing over time. The most recent monitoring events (2006 to 2008) indicated that the waste rock was creeping in a northerly direction at rates up to 6 cm per year. Based on evidence of ongoing deterioration of the Hudgeon Lake outlet, creek stabilization measures consisting of four gabion drop structures were constructed from 2002 to 2004 (Figure 26). Because the waste rock was still undergoing creep movements, and may do so for many more years, gabion drop structures were selected for the channel stabilization measures because they can accommodate some movements of the waste rock pile and remain functional. The gabion drop structures serve as grade control points connecting nearly flat channel sections.

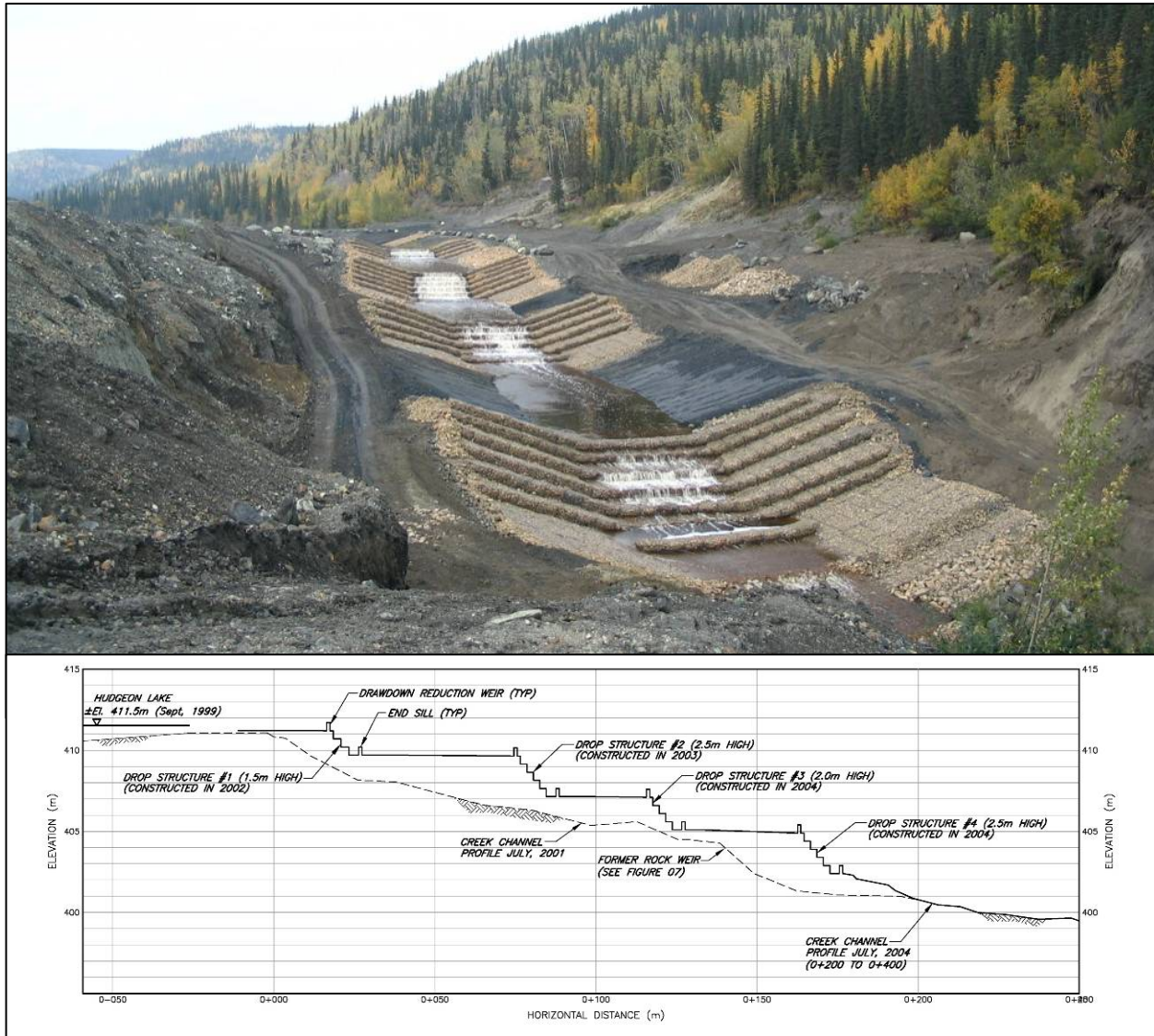


Figure 26 Clinton Creek Channel Stabilization Works (2004)

6.1.2 Current Physical Condition

Waste Rock Dump

Waste rock movement monitoring carried out since reactivation of the monitoring program in 1999 has confirmed that creep movements of the waste rock dump are continuing. The average horizontal movements for the monitoring interval from 2006 to 2008 range from 0 to 6 cm/yr which is about the same as measured in the previous monitoring period (2004 to 2006). There does not appear to be any significant difference between the movement rates in the upper, mid and lower portions of the waste rock dump, a behaviour indicative of a mass movement rather than individual blocks moving independently within the

waste rock. Settlement of the waste rock is also continuing at average rates ranging from 1 cm/yr in the lower portion of the waste rock dump to 4 cm/yr in the mid-slope area.

The movement magnitudes over the last few years have not resulted in any significant change in the physical condition of the dump. The majority of the major landslide features visible across the dump are associated with the large movements experienced during active mining and for a number of years thereafter. Since about the mid 1990's it appears that these movements have gradually tapered off to the rates now being observed. The result is a hummocky landscape characterized by slump blocks, remnants of tension cracking, and generally uneven ground, although many of these features have been masked by site work since active mining ceased. Vegetation of the dump is sparse although is slowly becoming established in sheltered areas on flatter portions of the dump and along the edges of the roads on the dump. Initial seeding trials have been undertaken by GY since completion of the gabion drop structures in 2004 in an attempt to establish some vegetation on the waste rock pile, these trials have not been widely successful, most likely due to the waste rock being a poor growth medium (personal communication, R. Pugh of GY). In 2008, a different trial approach to re-vegetation was undertaken that included willow staking and transplanting of native vegetation taken from along the mine access road. The success of these methods will be assessed in coming years.

Clinton Creek Channel

Measured deformation of the gabion drop structures appears to correlate with the magnitude of mass waste rock movement. By design, these structures can accommodate considerable deformation providing that flow is contained within the gabion baskets. To date, the measured deformation of the structures has not compromised the hydraulic capacity or stability of the structures (AECOM, 2009).

Since routine surveys were re-established in 1999, there has not been any significant down-cutting of the Clinton Creek channel across the waste rock dump. The channel across the waste rock pile is approximately 900 m long with Station 0+00 m located at the outlet from Hudgeon Lake. Aside from the localized variability associated with the limited repeatability of the survey i.e. where the survey shot is taken, it appears that the profile can be separated into four discrete stretches as shown on Figure 27 and summarized as follows:

Stretch 1 (Station 0+000 to 0+200): This is the stretch immediately downstream of the Hudgeon Lake outlet that has been stabilized with gabion drop structures. There is very little to no down-cutting evident since construction of the stabilization works represented by the 2004 profile. This was the stretch where significant down-cutting in the vicinity of the outlet was measured in 2001. During construction of the drop structures, up to 3 m of fill was added to the channel.

Stretch 2 (Station 0+200 to 0+325): This is a relatively straight stretch immediately downstream of the channel stabilization works at about a 2% grade, beginning close to the location where the channel bottom is down cut into the bedrock (Station 0+225 m) that exists on the natural valley slope. It is also one of the deepest channel sections relative to the access road which is up to 17 m above the channel bottom. Little to no down-cutting since 1999 is evident along Stretch 2.

Stretch 3 (Station 0+310 to 0+660): This is a relatively steep channel stretch with an average grade of about 5% with shorter segments in the order of 6%. Intermittent down-cutting of up to 1 m is evident along

short segments e.g. Station 0+425 to 0+500 but in other segments e.g. between Station 0+550 and 0+650, the channel appears to have been infilled by almost the same amount. The channel appears to be meandering along this stretch, possibly as a result of temporary blockages from bedrock or waste rock.

Stretch 4 (Station 0+660 to 0+800): This is the channel stretch at the downstream end of the waste rock dump where it transitions into the natural creek channel. It is relatively straight with an average grade of about 2.5%. There is no evidence of down-cutting, and in fact, deposition may be occurring along this stretch.

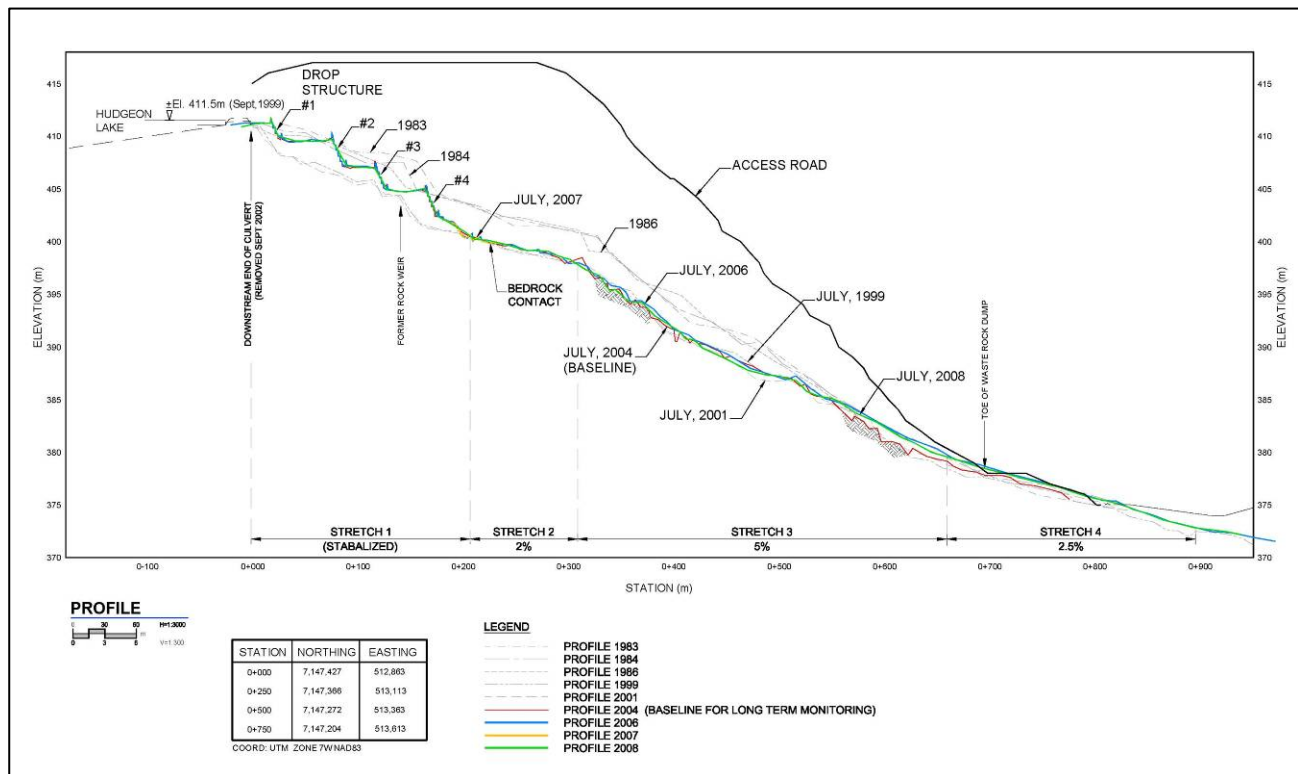


Figure 27 Clinton Creek Channel Profile

Identified Hazards and Risk Assessment

Before the Clinton Creek channel stabilization repairs were completed, the conditions at the former mine site potentially exposed individuals, property and the environment to an unacceptable risk mainly associated with flooding. Using available information, a qualitative assessment of risk scenarios and human and ecological exposure levels associated with a breach of the lake outlet was possible. A quantitative estimate of risk was not considered appropriate given the considerable uncertainty in parameters necessary to arrive at precise predictions of risk under various scenarios and circumstances. There was however, sufficient reliability in the results to determine the acceptability of potentially hazardous activities and develop guidelines for appropriate risk management strategies. In this regard, the level of risk downstream of the mine site was categorized as high, medium or low based on the severity of flooding within each zone (Figure 28). The

inherent risk to human health and potential loss-of-life is dependent upon the potential for human exposure within these zones.

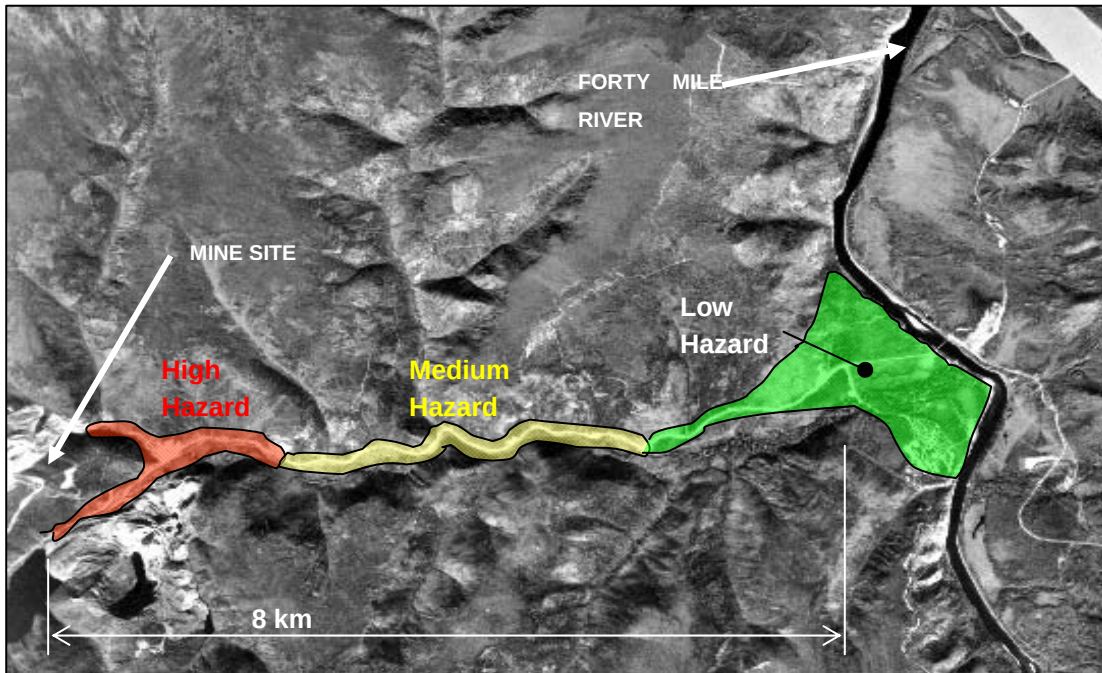


Figure 28 Downstream Hazard Map

The potential for loss-of-life associated with a breach is greatest immediately downstream of the mine site before a constriction in the Clinton Creek valley. Farther downstream along Clinton Creek, the risks are reduced, as the high water levels will be confined to the creek valley below the road where human exposure is less likely. The risk is considered low at the next most likely downstream area of occupancy in the vicinity of the former Clinton Creek Town-site where the valley widens considerably. Aquatic life and mammals downstream of the mine site are also potentially at risk from the redistribution of eroded waste rock. The largest risk is believed to be from a sudden breach of the waste rock dump (i.e. Hudgeon Lake outlet) resulting in fisheries habitat loss through downstream smothering and flooding. There is still however, a continued risk to aquatic and terrestrial life due to the chronic erosion and redistribution of waste rock downstream of the mine site.

For each of the ecological or human health risks identified, it has been an important consideration of the government to determine what level of risk should prompt a risk management or remedial strategy. In the interim between completing the risk assessment and completing the creek stabilization repairs an FM broadcast station was established and warning signs were posted to warn remote area travellers of the possibility of flash flooding. It is important to recognize however, that the channel stabilization works at the Hudgeon lake outlet have significantly reduced but not eliminated the risk of a breach.

Sediment Redistribution

Sediment redistribution downstream of the mine currently occurs chronically as a result of continuous erosion of waste rock along Clinton Creek where it passes through the waste rock dump and potentially as a result of a breach at the Hudgeon Lake outlet. Through the continuous process of erosion and deposition of coarse granular material in the general area of Wolverine Creek, Clinton Creek will cut new channels in this area during larger floods, possibly as often as on an annual basis. Along the intermediate reach, between the valley constriction and the top of the granular outwash fan, the channel will remain confined within the V-shaped valley with only minor lateral shifts. Along the granular outwash fan, Clinton Creek is unstable and will continue to seek new alignments indefinitely through an endless cycle of erosion and deposition with a corresponding change in profile. Although sediment deposition does not pose any direct threat to human life or property downstream of the mine site, some risk to riverine habitats and species may exist if geological slumping and erosion contribute to excessive sediment loads (RRU, 1999). The potential for deleterious effects on fish species and habitats from the chronic transport of sediment from the waste largely depends on the timing of release and downstream extent of sedimentation.

Erosion of waste rock is expected to continue indefinitely, although the rates of erosion may diminish if the waste rock dump reaches equilibrium. It must be recognized however, that the process is dynamic and continued down-cutting will soon re-establish contributions from unstable toe slopes and possible acceleration of mass downslope movements. The impact from waste rock erosion and sediment outwash into the downstream channel is most significant immediately downstream of the toe of the waste rock dump. During turbulent flow conditions, waste rock material will gradually move downstream towards the Wolverine Creek confluence. In this area, the valley is significantly wider and the coarser material will deposit in pockets of low flow velocity while the finer material will be carried farther downstream. It is likely that a large part of the gravel fraction is being deposited in the wide area just downstream of Wolverine Creek and in the two wider and flatter areas along Clinton Creek, just upstream of Eagle Creek. Similarly, it is likely that the coarsest material, such as cobbles and boulders, are accumulating in the vicinity of Wolverine Creek. The sand fractions of the waste material can most likely be found deposited in pockets throughout the length of Clinton Creek, possibly as far downstream as the Forty Mile River.

6.1.3 Closure Options

Continued Care and Maintenance (Status Quo)

General care and maintenance of the waste rock dumps at the former Clinton Creek Asbestos Mine currently consists of instrumentation monitoring and general inspection and maintenance work, particularly for the Clinton Creek channel stabilization works. The annual costs to maintain this status quo management practice are orders of magnitude less than those associated with mine closure options. These costs however, will carry forward into the foreseeable future and must be weighed against the one time capital costs for closure. It must also be recognized that the current care and maintenance costs are largely dependent on maintaining the current acceptance of the risks associated with a breach of the waste rock dump and the chronic redistribution of waste rock and asbestos fibres into the receiving environment downstream of the mine. The potential environmental liability associated with the status quo option however, should consider the potential for future changes in the risk associated with the physical stability of the waste

rock e.g. development or other activities downstream of the mine and/or more restrictive limits on the release of mine waste and asbestos fibres, either air or water borne into the environment.

Even with continued maintenance of the drop structures at the Hudgeon Lake outlet, continued waste rock movements will eventually compromise the integrity of the channel stabilization works to a point where upgrading or replacement of the structures will be required. Based on the current horizontal waste rock movements, and how the structures deform as a result of the movements, it is estimated that remedial work or replacement may be necessary in about 10 years time, or about 2019. Left unattended, the condition of the structures can be expected to deteriorate with time and eventually reach a point where they no longer provide the necessary protection against the retrogressive channel down-cutting observed before construction of the stabilization works. When this point is reached, the breach potential will increase as will the associated risks to humans and property associated with downstream flooding and debris flows.

It is also possible that a failure of the north (natural) valley slope could cause a blockage of the channel. In this circumstance, water would temporarily be ponded upstream of the blockage until a breach occurs or the creek channel cuts a new channel e.g. into the waste rock along the road. The likelihood of this would depend on the elevation of the blockage with respect to the access road (Figure 27). If the constriction were to occur close to the stabilized channel section e.g. in Stretch 2, it is possible that the lower gabion structures could be submerged and perhaps bypassed when the channel blockage is breached.

Convey Creek Flow Along Existing Alignment

Given the slow rates of horizontal waste rock movement, the conveyance of water along the existing alignment across the entire waste rock dump is considered feasible. There are a number of constraints that must be recognized however, in the design of channel stabilization measures for long term closure. These include:

- Continued creep movements of the waste rock that may distort or shift structures,
- Floating debris from Hudgeon Lake such as logs and ice that may impede flow, or cause damage to structures in the creek channel,
- Directing flow from Hudgeon Lake around the construction area to provide longer construction windows, and
- Remoteness of the site with respect to availability and delivery of construction materials and equipment.

The channel stabilization work would involve flattening the channel profile using grade control structures such as gabion drop structures. The works would likely be an extension to the channel stabilization measures constructed at the Hudgeon Lake outlet. Stabilization of the waste rock would be provided by infilling the channel and regrading the upper portions of the waste rock dump. Infilling the existing creek channel would also help address concerns with respect to valley slope instabilities.

The flatter channel grade would reduce the water velocity such that it can no longer scour or erode the bed of the creek channel. The grade between the drop structures can be maintained by adjusting the number, height and location of the drop structures and the channel section can be set to the required width and depth

to pass the expected creek flows. As a consequence of stabilizing the channel and reducing the sediment load, some increased erosion of the Clinton Creek channel downstream of the stabilized portion of the channel may occur as a result of the reduced bed load.

The flow from Hudgeon Lake is recognized as being highly variable and sensitive to precipitation events within the drainage basin. Dewatering of the channel was required during construction of the stabilization measures constructed to date and would be a critical consideration for future works farther downstream. To maintain a base flow in the channel to provide longer construction windows and also to maintain fish habitat it will be necessary to divert some flow from Hudgeon Lake around the work area, measures that would become increasingly difficult the farther downstream the works are constructed.

Convey Creek Flow Over the Waste Rock Dump

This option would allow flow to be maintained in the existing channel while earthworks associated with regrading the waste rock dump and constructing the new channel was underway. This would greatly simplify the issues around dewatering and/or re-routing creek flow associated with channel stabilization works along the existing alignment. The channel would likely be lined with gabion drop structures or something similar and might include a drop structure at the tail end to minimize the depth of excavation through the waste rock material. The existing channel would be filled as part of the overall regrading works to stabilize the waste rock.

Convey Creek Flow Around the Waste Rock Dump

The conveyance of water from Hudgeon Lake around the waste rock dump via a tunnel has been previously considered. The inlet structure for the tunnel would be located away from active waste rock movement on the north side of the valley. The outlet would most likely be on the west side of the Wolverine Creek valley resulting in a tunnel about 2.2 km long. It has been estimated that a minimum tunnel diameter of about 3 m would be required. The existing channel over the waste rock dump would serve as an emergency spillway should the tunnel entrance become blocked.

Valley Restoration

Of all options considered to date, completely draining Hudgeon Lake by removing the waste rock blockage is the only alternative that restores natural creek drainage through the Clinton Creek valley. The work would have to be completed in stages to gradually lower lake levels as excavation work proceeded. A sufficient volume of material would have to be removed to provide adequate hydraulic capacity through the valley and allow for sloughing of thawed valley slopes likely to occur below the present water surface. The remaining waste rock could be flattened for long term stability. By disposing of excavated waste rock material in the Porcupine Pit, it may be possible to address the concerns with respect to pit wall stability and public safety i.e. the material could be placed against the pit wall to improve stability and flatten the pit wall slopes.

6.1.4 Information Gaps

Additional information is required to move forward with selection, design and construction of a long term closure option. Closing the information gaps is somewhat dependent on the option under consideration but in most cases will require continued monitoring and field investigations to determine soils and groundwater conditions, the presence and stability of permafrost and the engineering properties of soils. The major gaps identified are summarized as follows:

Movement Monitoring

While the collection of additional movement monitoring data is not necessarily an information gap, it is likely that additional monitoring points would be established to further evaluate the nature and magnitude of horizontal and vertical movements of the waste rock. The current level of movement monitoring data would be sufficient to proceed with the design of valley restoration or tunnelling options.

Field Investigations

Additional geotechnical and groundwater information is required to proceed with all options except perhaps valley restoration. These investigations would focus on determining the nature of the soils beneath the waste rock dump, in particular the soil properties (strength), permafrost conditions and groundwater pressures. This information is necessary for the stability analysis associated with determining the necessary channel infilling and waste rock regrading (off-loading) to achieve adequate long term stability. An extensive investigation of the bedrock along the proposed tunnel alignment would also be required if this (convey water around the waste rock dump) alternative is considered further.

Sediment Transportation and Deposition

The impacts of potential smothering of salmon habitat, including spawning/rearing grounds from the chronic redistribution of waste rock material in Clinton Creek have not been quantified.

6.2 Open Pits

6.2.1 Historical Summary

The three principal chrysotile asbestos ore bodies within the overall Clinton Creek Mine were named Porcupine, Snowshoe and Creek. Development of the three open pits is not well documented in the available reports. It does however appear that movements of the west wall of the Porcupine Pit may have contributed to the decision to terminate ore recovery in this pit. A generalized section through the Porcupine Pit (taken from an untitled brochure prepared by Cassiar), shows the geological fault and ore body in comparison to the argillite and serpentine overburden materials destined to the waste rock dump (Figure 29).

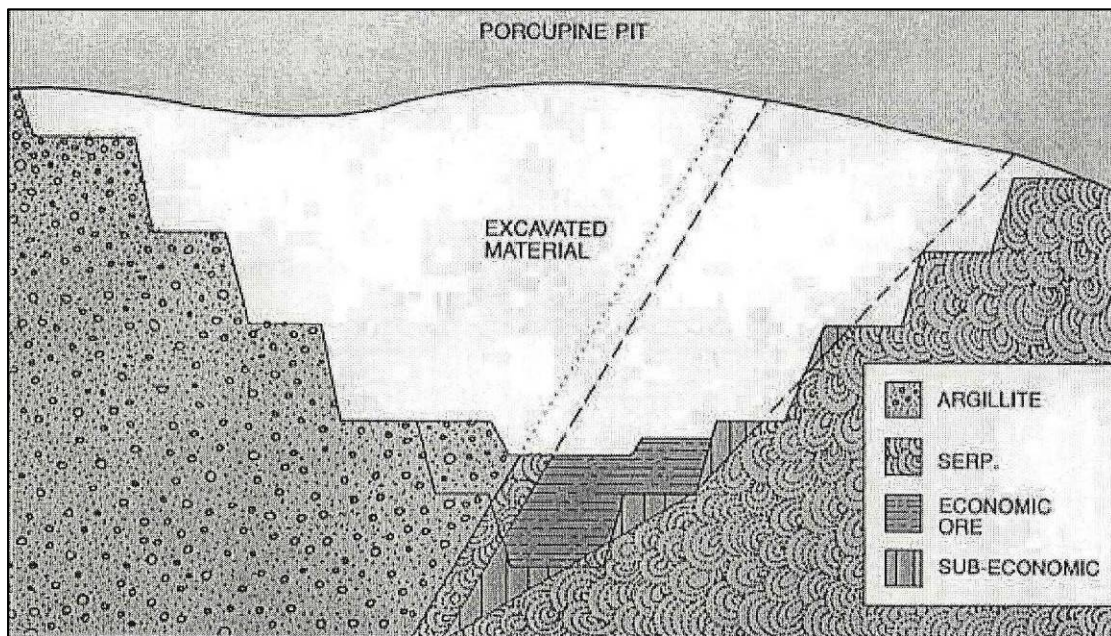


Figure 29 Porcupine Pit Cross Section (view NE)

6.2.2 Current Physical Condition

The physical condition of the open pits has not been evaluated as frequently as the waste rock dumps and tailings piles. The last physical inspection was carried out during the hazard assessment program completed in 2003 (UMA 2004). The most recent survey of a few existing pit wall monitors at the Porcupine Pit was completed in 2008 as part of the Long term Performance Monitoring program (AECOM 2009). Pit wall instabilities are evident at all three pits with visible tension cracking and slumping of large sections of ground around the pit perimeters (Figures 30, 31 and 32). In 2003, many of these instabilities and associated movements appeared recent and during the site reconnaissance, small active slides were observed in the northwest corner of the Porcupine Pit. All three pits have ponded water.



Figure 30 Porcupine Pit in 2003 (view N)



Figure 31 Snowshoe Pit (2003)



Figure 32 Creek Pit (2003)

6.2.3 Identified Hazards

The main hazards previously identified at the open pits are ground movements associated with instabilities of the pit walls, rock falls and the presence of exposed asbestos ore (UMA, 2004). The most obvious hazard is associated with sudden failures of the pit wall or rock falls into the open pits. The likelihood of both occurrences is increasing with time as the overburden and waste rock material weathers. Risks associated with rock fall hazards are associated with all three pits, in particular the Creek Pit where there is a pond possibly used for swimming. In 2004, the areas with raw unprocessed ore, including asbestos fibres at the entrance to Porcupine Pit and directly west of the former crusher building were regraded. In 2004, the access road to the Snow Shoe and Creek Pits was blocked as well as the entrance to the Snow Shoe Pit during site clean-up work carried out on behalf of the Government of Yukon. However, the boulders blocking access routes have in some cases been moved by unknown individuals so their effectiveness is limited. The Government of Yukon undertook trenching and berming work and signage installation in 2006 around the perimeter of the Porcupine Pit to provide warning and limit access to the edge of the pit.

6.2.4 Closure Options

Continued Care and Maintenance (Status Quo)

General care and maintenance of the three open pits at the former Clinton Creek Asbestos Mine currently consists of restricting vehicle access to the open pit areas. Without measures to physically alter the open pit slopes i.e. slope flattening or constructing toe berms, stability of the pit walls will only be achieved when they eventually reach a stable angle which will take many tens or hundreds of years. This natural process is well underway as evidenced by the ravelling of pit walls, in particular at the Porcupine Pit (Figure 30). It is recommended that future site inspections include the open pits and that additional movement monitoring points be installed to help assess the performance of the pit walls.

Pit Infilling

It is possible that one or more of the alternatives to stabilize the waste rock dump or tailings piles would involve infilling the open pits with either waste rock material and/or tailings. This alternative would provide an opportunity to dispose of the excavated material in a readily available and previously disturbed area while at the same time possibly stabilizing the open pit walls. Alternatively or in combination with pit infilling, it would be possible to flatten the over-steepened open pit wall slopes.

6.2.5 Information Gaps

It would be necessary to determine the discharge criteria for pond water in the open pits to determine if it is suitable for direct discharge or if treatment is required. The volume of the open pit would also need to be determined to develop an infilling model to determine the optimum placement of material. Should it be deemed necessary to quantify the risk associated with pit wall failure, a drilling program would be required to support a detailed stability analysis.

6.3 Porcupine Creek Waste Rock Dump

6.3.1 Historical Summary

Waste rock was placed across the Porcupine Creek valley slope as shown on Figure 33, one of the earliest aerial photographs taken of the area in 1976 or 1977 (Hardy, 1977). The most northerly section of the dump was placed at least partially up the east valley slope and this area has remained relatively stable. Sections near the centre of the dump which were placed farther away from the east valley toe, however, experienced slumping that created blockages to creek flow at two locations. Both blockages behave as permeable dams with creek flow through or beneath the rock fill.

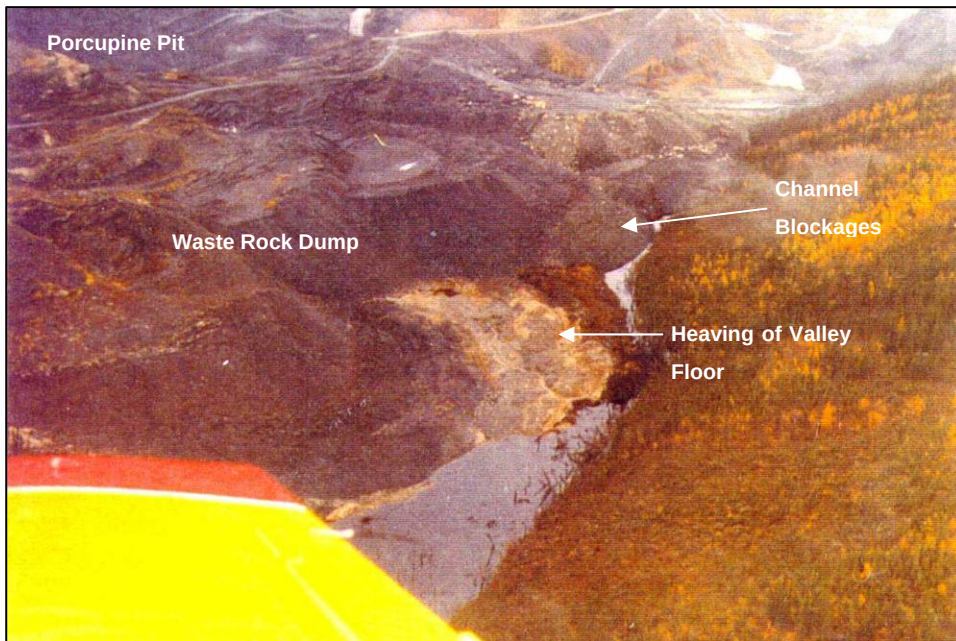


Figure 33 Porcupine Cr. Waste Rock Dump (1977)

The southern area of the waste rock dump has undergone extensive movement at the crest and toe due to both the volume of waste rock and the method of placement. Dumping probably would have begun at or near the crest of the original valley slope but was only advanced across a portion of the valley. Instabilities of the waste rock pile heaved the valley floor several metres resulting in the primary impoundment seen today. Near the crest of the waste rock dump, movement has resulted in numerous tension cracks and slump blocks as shown on Figure 34 (Geo-Engineering, 1988).



Figure 34 Upper Area of Waste Rock Dump (1988)

6.3.2 Current Physical Condition

At present, considerable downslope movements are continuing in the upper portion of the waste rock dump. Impounded water upstream of the waste rock dump continues to flow either below or through the waste rock or along the east valley slope in subterranean channels. The majority of flow occurs via a drainage channel incised through the slide debris from the unstable southern portion of the waste rock where it enters the waste rock pile (Figure 35). Water draining through the dump has been observed to discharge through the waste rock about 5 m above the toe of the north slope, approximately 550 m to the north of the inlet. Localized slumping of the waste rock is evident at the discharge point as illustrated in Figure 36. Water is subsequently conveyed along a drainage channel incised along the south edge of the road where it eventually spills into the Creek Pit. Creek flow is also occurring via subterranean flow along the toe of the waste rock and east valley slope where flowing water is visible below the organic mat on the valley slope. Discharge from the subterranean flow system occurs as a small spring near the northwest corner of the waste rock dump.



Figure 35 Creek Flow Entering Waste Rock (1998)



Figure 36 Creek Flow Outlet in Waste Rock (1998)

6.3.3 Identified Hazards

Although the potential exists for a sudden release of water due to a breach of the waste rock pile, the consequences of a failure are not considered serious given the relatively small catchment area i.e. the volume of water stored in the upstream pond is small (UMA, 2004). The most significant physical hazards are believed to be associated with uneven ground, open tension cracks and potential exposure to asbestos ore and fibres.

6.3.4 Closure Options

Continued Care and Maintenance (Status Quo)

The Porcupine Creek waste rock dump is not currently included as part of the routine inspections of the mine site. Inclusion of this area is recommended for future inspection works. There have not been, nor is it considered necessary at this time, to consider long term closure plans for the Porcupine Creek waste rock dump. This recommendation can be reviewed after routine inspections have been carried out.

6.3.5 Information Gaps

No information gaps have been identified.

6.4 Wolverine Creek Tailings Piles and Channel

6.4.1 Historical Summary

The failed tailings piles have been historically referred to as the north and south lobes. The south lobe failed suddenly in early 1974 and the tailings moved down the west valley slope completely blocking flow in Wolverine Creek. The blockage was subsequently breached releasing a significant amount of water borne tailings into the downstream environment as shown on Figure 37. Remedial works, including the removal of tailings was undertaken soon after the breach occurred. Following the 1974 failure, downslope movements of the south lobe continued resulting in occasional channel blockages. In 1978, a mid-slope portion of the south lobe was terraced in an attempt to off-load this area and slow the advancement of the lobe.

Following the failure of the south lobe, tailings were placed farther to the north in the north lobe. However, downslope movements of the north lobe began almost immediately and tailings were then placed farther to the northwest on flatter ground until mining operations ceased in 1978. The advancement of the north tailings lobe can be seen in the aerial photograph in Figure 38. By 1986, the north lobe had reached the east valley slope as seen in Figure 39 (Klohn, 1986). The lighter colouration in the upper portion of the tailings pile represents relatively undisturbed tailings while the darker tailings are indicative of heavily disturbed material. Significant heaving of the valley floor also occurred along the north side of the lobes, resulting in a narrowing of the upstream section of the creek channel and the formation of two small upstream ponds (Figure 40). As the lobes advanced over the years, the leading edge was being eroded and the tailings transported downstream. It is believed however, that the tailings advanced faster than they were being eroded as evidenced by mounding and lateral spreading at the toe. A rock lined channel incorporating a

series of rock weirs was constructed immediately downstream of the south lobe in 1978 to prevent down-cutting of the channel over the tailings. The weirs are visible in Figure 39.

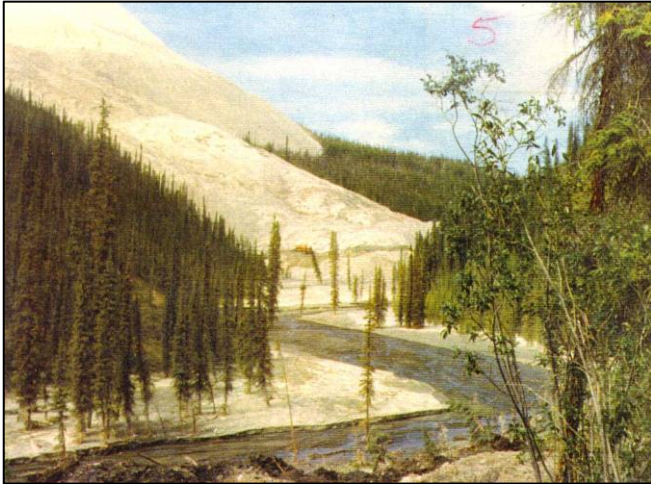


Figure 37 Cr. Channel D/S of Breach (1974)



Figure 38 Advancing N Lobe (1977)

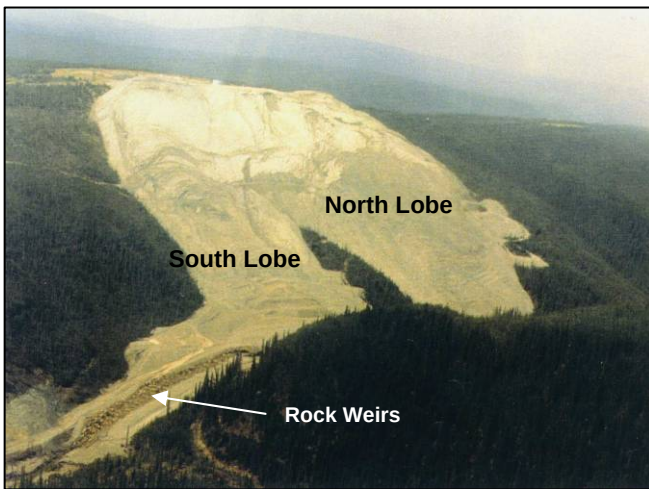


Figure 39 Failed N & S Lobes (1986)



Figure 40 Pond Between N & S Lobes (1998)

6.4.2 Current Physical Condition

The tailings are continuing to advance downslope although at slower rates that previously observed. It has also been confirmed that significant mounding and spreading of the tailings is occurring as the passive resistance to sliding develops. The leading edge of the tailings is very steep and material frequently slumps into the creek channel (Figure 41). The result is a continual process of tailings being eroded along the leading edge of the lobes eroding tailings and gradual advancement of the tailings mass. Evidence of movements extends to the top of the tailings pile as seen in Figure 42. A crust formed on the surface of the

tailings has greatly reduced air-borne asbestos. Seeding trials on the tailings have not proved very successful, likely due to the poor growth medium (personal communication, R. Pugh). The rock lined portion of the channel downstream of the south lobe is currently in reasonably good condition.



Figure 41 Toe of Tailings in 1998 (view D/S)



Figure 42 Crest of S Lobe (1998)

6.4.3 Identified Hazards

Hazards associated with the current physical condition of the tailings piles include a potential breach of tailings blocking the channel, the presence of airborne asbestos fibres and the chronic redistribution of waste material including asbestos fibres into the downstream environment. The risks to humans and property associated with a breach of the tailings are discussed in UMA's Risk Assessment Report (UMA 2000). The consequences of a breach of the tailings are considered less severe than a breach of the Hudgeon Lake outlet because the volume of water stored upstream of the tailings is small in comparison to the waste rock dump. Also, the rock-lined channel and rock weirs downstream of the south lobe, installed in 1978, help reduce the likelihood of a breach. Although the rock lined channel has performed reasonably well over the years, continued care and maintenance will be required to maintain its serviceability.

A thin crust formed over time on much of the tailings mass appears to have significantly reduced the release of fugitive asbestos fibres compared to conditions during active milling operations. However, air samples collected during site investigation activities suggest that the potential remains for asbestos fibres to become airborne either by human activities, movements of tailings from instabilities of the pile(s), or environmental effects such as erosion from wind or surface water run-off. The need for remedial work on the tailings to reduce the level of fugitive asbestos fibres was assessed using air monitoring results from 2004 during construction and demolition activities (UMA, 2005).

Wolverine Creek appears to have the capacity to remove tailings at a sufficient rate to keep up with the downslope movements of the north and south lobes as evidenced by active erosion of the leading edge of the north and south lobes. Sediment transport of asbestos tailings can be clearly seen within the Wolverine

Creek channel as far as its confluence with Clinton Creek, in particular immediately upstream of the culvert where the tailings are dammed by the mine site access road. Although sediment transport in Clinton Creek is less noticeable (visually), small pieces of tailings can be readily found in the vicinity of the culverts.

Sediment Redistribution

Based on the gradation of the tailings, and the estimated flow velocities, approximately 50% of the material eroded from the tailings pile will be transported during all flows that occur on Wolverine Creek and carried down to Clinton Creek from where it will be carried by the Clinton Creek flow farther downstream. As with the finer material from the waste rock pile, it is likely that the finer fractions of the mine tailings are carried down to Forty Mile River, with the clay fraction possibly remaining in suspension down to the Yukon River. Some of the finer tailing material may also have accumulated on the wide bar on the right side of Forty Mile River, immediately downstream of the Clinton Creek bridge across Forty Mile River. However, it is uncertain whether this bar has been caused by discharges from the placer mining operations along Forty Mile River or by mine tailing material discharges from Clinton Creek.

6.4.4 Closure Options

Continued Care and Maintenance (Status Quo)

General care and maintenance of the tailings piles at the former Clinton Creek Asbestos Mine currently consists of instrumentation monitoring and general inspection and maintenance work, particularly along the rock stabilized channel section. As with the waste rock dump, the annual costs to maintain this status quo management practice are orders of magnitude less than those associated with mine closure options. These costs however, will carry forward into the foreseeable future and must be weighed against the one time capital costs for closure. It must also be recognized that the current care and maintenance costs are largely dependent on maintaining the current acceptance of the risks associated with a breach of the tailings piles, the chronic redistribution of tailings into the receiving environment downstream of the mine and the release of asbestos fibres, either air or water borne into the environment. To reduce the risk of exposure to fugitive asbestos fibres, continued maintenance of measures to cover exposed asbestos fibres and restrict site access will be required.

The potential environmental liability associated with the status quo option however, should consider the potential for future changes in the risk associated with the physical stability of the tailings pile e.g. development or other activities downstream of the mine and/or more restrictive limits on the release of tailings and asbestos fibres, either air or water borne into the environment.

Valley Restoration

Of the options considered, removal of the tailings blocking the valley is the only alternative that restores natural creek drainage through the Wolverine Creek valley. Restoring the valley and the associated natural drainage has the benefit of significantly reducing or eliminating the risk associated with a breach of the tailings by the impounded water and the concern of chronic downstream sedimentation of tailings. To facilitate construction, drainage of the impounded water could be accomplished using pumps and/or siphons

before removing tailings from the valley bottom. Removal of tailings from the side slopes of the valley would have to start at the upper slope and proceed in a downslope direction to prevent the development of slope instabilities. Based on previous monitoring and results from the slope stability analysis, it is anticipated that a portion of the tailings at the top of the valley could be stabilized by re-grading.

Based on existing cross sections, approximately 4,000,000 m³ of tailings would have to be excavated to achieve a stable geometry. The excavated material could be disposed of in the open pits on the south side of Clinton creek and/or along the top of the ridge at the former mill area. An additional 1,000,000 m³ of re-grading would be necessary to achieve stability of the tailings in the upper slope area. The potential for airborne asbestos would be significant and it is certain that extraordinary measures would be required to provide protection to workers and the environment if this alternative is implemented.

Convey Creek Flow Over Tailings

The long term success of conveying water over the tailings in the bottom of Wolverine Creek valley is contingent on stabilizing the north and south lobes of the tailings pile. Once the tailings have been stabilized, water could be conveyed over the tailings in a channel that has been stabilized to minimize erosion. Conveyance of water through culverts buried in the tailings is not considered practical given the potential settlement and horizontal creep movements of the tailings and the potential for failure and/or blockages of the culvert.

The revised geometry for the stabilized tailings pile would be accomplished by re-grading the tailings to off-load material (reduce driving forces) from the upper portion of the slope and adding material at the toe (increase resisting forces). Two cases were analyzed in UMA's Environmental Liability Report; the first case assumes that the entire tailings pile, including the portion upslope of the head scarps, is unstable and has to be regraded. The second case assumes that the tailings upslope of the head scarps can be stabilized independently of the active slide material. In both cases, the creek channel would be routed across the toe of the tailings. Both cases included in-filling the ponded areas between the north and south lobes (to the same final elevation as the north and south lobes) and upstream of the north lobe (to approximately the same elevation as the existing water surface). Filling these areas would reduce the volume of water impounded after regrading the tailings and decrease the potential for a breach by increasing the length of the channel across the tailings.

Depending on the time of year when construction is undertaken, it may be necessary to control discharge from Wolverine Creek. This could be accomplished by drawing down the impounded water level prior to construction and/or filling in the existing channel through the tailings and allowing water levels to rise upstream of the tailings for the construction period. Alternatively, the average creek flow and impounded water level could probably be maintained by pumping or diverting the water flow around the construction site.

For both cases, a new channel would have to be constructed across the toe of the re-graded tailings. The new channel would require erosion protection and should be compatible with any creep movements of the tailings pile that may occur following regrading. In this regard, channel stabilization across the regraded north and south lobes would be achieved using a relatively flat grade and lining the channel to resist erosion. Rigid structures (e.g. concrete linings) should be avoided due to the risk of cracking and subsequent failure.

A transition between the new channel across the tailings and the existing rock-lined channel would be required to achieve the necessary hydraulic drop of 10 to 17 m. This transition could be constructed using gabion drop structures and appropriately sized granular materials.

The tailings on either side of the channel would be graded smoothly towards the rock-lined channel and any existing gullies filled with tailings. Run-off water could be slowed down by placing small check dams made of rocks across the tailings in a 'V' pattern pointing down slope. The presence of vegetation along the rock lined portion of the channel suggests that it may be possible to establish vegetation in the tailings adjacent to the rock-lined channel if moisture can be preserved to support plant growth (Figure 43). Since the establishment of vegetation would help to provide long-term stabilization of the tailings, growth could be encouraged by spreading organic matter such as wood chips, mulch or coniferous trees over the tailings in this area. Rehabilitation of the channel outlet at the confluence with Clinton Creek should also be considered to prevent future overtopping and potential washout of the mine access road and erosion at the downstream end of the culverts.



Figure 43 Vegetation Along Rock-Lined Channel (1998)

Convey Creek Flow Around Tailings

Conveyance of flow from Wolverine Creek around the unstable tailings through a concrete lined tunnel or directionally drilled, steel or PVC lined tunnel was also considered. The inlet structure for the tunnel would likely be located upstream of the north lobe on the east side of the valley. The outlet would be located in the Wolverine creek valley near the down stream limit of the rock-lined channel. The total length for the tunnel

alignment would be approximately 700 m. It would be necessary to partially infill the valley at the toe of the tailings pile to approximately elevation 412 m to construct an emergency overflow channel in the event the tunnel entrance is blocked. It is estimated that a tunnel diameter on the order of 2 m would be required to convey the estimated 200-year flood. The full supply level (FSL) would be set around elevation 405m (approximately the current impounded water elevation) and the crown of the tunnel would be placed at the same level. Permanent access to the inlet of the tunnel for future cleaning and maintenance could be achieved by constructing a road across the toe of the re-graded tailings. A short section of the road might have to be constructed along the east side of the valley in order to reach the outlet.

6.4.5 Information Gaps

Additional information is required to move forward with the selection, design and construction of a long term closure option. Closing the information gaps is somewhat dependent on the option under consideration but in most cases will require continued monitoring and field investigations to determine soils and groundwater conditions, the presence and stability of permafrost and the engineering properties of soils. The major gaps identified are summarized as follows:

Movement Monitoring

While the collection of additional movement monitoring data is not necessarily an information gap, it is likely that additional monitoring points would be established to further evaluate the nature and magnitude of horizontal and vertical movements of the tailings. The current level of movement monitoring data would be sufficient to proceed with the design of valley restoration or tunnelling options.

Field Investigations

Additional geotechnical and groundwater information is required to proceed with all options except perhaps valley restoration. These investigations would focus on determining the nature of the soils beneath the tailings pile, in particular the soil properties (strength), permafrost conditions and groundwater pressures. This information is necessary for the stability analysis associated with determining the necessary regrading to achieve adequate long term stability. A detailed investigation of the bedrock along the tunnel alignment would be required if this alternative (convey water around the tailings) is considered further.

Sediment Transportation and Deposition

The impacts of potential smothering of salmon habitat, including spawning/rearing grounds from the chronic redistribution of tailings in Clinton Creek are unknown.

Water Borne Asbestos

The effects of asbestos fibres on the aquatic environment have not been well researched. YG-AAM is currently undertaking a review of available information.

6.5 Site Infrastructure

6.5.1 Mine and Mill Site

Since the hazard mitigation work undertaken in 2004, there is very little left of the infrastructure associated with the former mining and milling activities. Many of the significant features e.g. the crusher building have been demolished. Some of the mining equipment (drill and shovel) is still located on the site. Demolition materials were landfilled on site. While some of the infrastructure was not demolished because of their size e.g. Tram Tower #3, hazards associated with the remaining structures have been addressed e.g. ladders removed. A list of major infrastructure identified in UMA's 2004 Hazard Assessment and the mitigation measures undertaken since 2004 is provided in Appendix A. Many of the areas e.g. mill site have been graded to cover asbestos fibres and other hazards e.g. backfilling of open pits.

6.5.2 Access Road

The gravel access road from the Top of The World Highway to the Forty Mile River crossing is currently maintained by the Yukon Government Department of Highways and Public Works in the summer months only. The road from the Forty Mile River bridge to the mine site is not maintained by YG-HPW. From time to time, culvert washouts and other minor repairs have been undertaken by YG-AAM to maintain access to the site for project activities and monitoring. Some maintenance work (e.g. clearing brush along the road) was done on the road into the mine from the Forty Mile River crossing to facilitate mobilization and demobilization for the channel stabilization and demolition activities. These activities have improved the ability to access the mine site which may not be desirable from a risk management perspective. Warning signs are in place regarding floods and other site hazards; however, the mine access road past the Forty Mile river bridge is still used by various area land users and tourists.

The wooden bridge crossing Clinton Creek at the downstream end of the waste rock dump washed out in 1997 and is no longer useable. Vehicles crossing Clinton Creek at this location must do so over a ford crossing, an obstacle that prevents some but not all access beyond this point. This ford crossing quickly degrades as a result of creek bed erosion, particularly after the spring freshet. From the ford crossing to the Hudgeon lake outlet, the majority of the access road is located on the waste rock dump and runs along the south edge of Clinton Creek. Localized failures of the waste rock have occurred in the past that extend back to the edge of the road. While the road has not been directly impacted by these instabilities to date, such events could occur in the future. Access to the Mill Site area requires vehicles to cross Clinton Creek at the Hudgeon lake outlet over another ford crossing. The road from this ford crossing to the mill site is steep and there have been previous washouts that have required repair to allow safe vehicle access. It is possible that this section of the road will become impassable at a few locations in the future without maintenance or repair work.

It is desirable for YG AAM to keep the access road in a useable state while continued care and maintenance and monitoring are necessary. Long-term access to the road needs to be considered in the overall closure planning for the site given that risk from the site would be reduced by limiting access, but some area users may be affected by such limits.

6.6 Air Quality

6.6.1 2003 Hazard Assessment Program

During the 2003 Hazard Assessment field program it was observed that the extent of asbestos across the site was far more extensive than originally thought and therefore a hazard identification field program was established and completed in two stages (UMA, 2004). The first stage involved identifying physical hazards, monitoring of waste rock and tailings pile movements and limited air sampling carried out during the field activities. The second stage was undertaken to further understand the potential human health and ecological hazards at the mine site related to water quality issues and airborne asbestos fibres. The following observations and conclusions were made with respect to the presence of asbestos fibres and air quality:

- There were isolated pockets of asbestos fibres within the open pits and waste rock dumps that may become airborne as a result of personal or demolition activity,
- Asbestos fibres were widely spread across the mill site and surrounding areas in various concentrations during milling operations. Significant amounts of asbestos fibres were found at the tram line terminus building, the conveyor tunnels, on the two concrete utilidor box structures and in the area of the former dry rock building, the service building and the mill building,
- Air monitoring results collected during the field program in 2003 indicated that human activity on the mill site could result in airborne asbestos fibres, and
- Although airborne fibre levels measured indicated concentrations were below the Yukon 8-hour permissible exposure limit of 0.5 fibres/ml, it was expected that exposures would be higher than those measured to date during construction, demolition or certain types of recreational activity, particularly under dry site conditions.

An air sampling program was recommended to assess asbestos concentrations in the air throughout the former mine site including the former air strip, mill site, tailings pile, open pit areas, waste rock dumps and crusher building area.

6.6.2 2004 Air Monitoring Program

An air monitoring program was undertaken following the 2003 Hazard Assessment program given the widespread presence of loose asbestos fibres at the mine site. The purpose of the air monitoring program was to provide site specific data that could be used to evaluate the risk of asbestos inhalation due to occasional site visits. The air monitoring program was undertaken in July and August 2004 while personnel were on-site for the Clinton Creek Channel Stabilization Work. Air monitoring results collected during the demolition work were not included in the SLRA Report (UMA 2006) since they did not relate to the ambient conditions before or after the demolition work.

Sixty air samples (50 area and 10 personal samples) were collected at various locations on the mine site. The area samples represented ambient air conditions and the personal samples represented conditions while traversing various areas of the mine site by foot, all-terrain vehicle (ATV) and automobile. Each area sample was collected by setting up an air sampling pump at one location for the duration of the sampling period. Personal samples were worn by people moving around the site by automobile, ATV, walking or in

one case, while operating a bulldozer. Weather conditions were recorded using a weather station setup at the Mill Site equipped with a data logger and the following sensors: rain gauge, temperature, dew point temperature, relative humidity, wind speed and wind direction.

Air Monitoring Program Results

Air samples collected in 2004 were analyzed by Phase Contrast Microscopy (PCM) and selected samples were analyzed by Transmission Electron Microscopy (TEM). The PCM method is an economical test that does not differentiate between non-asbestos and asbestos fibres, and thin fibres (i.e. less than about 0.25 micrometres in diameter) are not detected by PCM. TEM is a considerably more expensive test but provides for the identification of both asbestos and non-asbestos as well as thin fibres in air.

The testing results of the 60 air samples analyzed using PCM showed that 45 of the 50 area samples were below the calculated analytical detection limit. Five samples were above the detection limit with levels ranging from 0.001 fibres/ml (crusher building) to 0.01 fibres/ml (Wolverine Creek). Airborne asbestos results for the 6 area samples tested using TEM ranged from <0.001 to 0.002 fibres/ml. These values are comparable to the PCM results and confirm that airborne asbestos at the area monitoring stations are near or below detection limits.

The PCM results for the 10 personal sampling events ranged from 0.03 to 0.074 fibres/ml. The meteorological conditions during the 2004 sampling events did not appear to have a significant impact on the personal sampling results. The highest recorded wind conditions and corresponding dry conditions during the August 24, 2004 sampling period did not produce the highest airborne asbestos results. Physical activities, including walking, sample deployment and recovery, and driving an ATV resulted in higher levels of airborne asbestos than the area monitoring values. All of the personal samples collected recorded values greater than the calculated analytical detection limit. The asbestos fibre concentrations for the eight personal samples submitted for TEM testing ranged from 0.008 to 0.118 fibres/ml. The TEM asbestos fibre concentrations for the personal samples were significantly higher than the results from the area samples and confirm, similar to the PCM analysis, that physical activity in specific areas of the former Clinton Creek mine site will significantly increase the concentration of airborne asbestos fibres. In general, these levels were lower than measured in 2003 and indicated that the remedial activities undertaken in 2004 reduced airborne asbestos fibre concentrations. In all cases however, airborne asbestos fibre levels measured were below the Yukon 8-hour permissible exposure limit of 0.5 fibres/ml.

6.6.3 Screening Level Risk Assessment

In 2003, SENES Consultants Limited provided a screening environmental risk assessment (SLRA) of the former Clinton Creek Mine site, as part of a series of SLRAs of eleven mine sites and thirteen former military sites in northern Canada on behalf of INAC (SENES, 2003). The SLRA included a statistical assessment of the 1998 field data from the RRU (1999) report to determine appropriate concentrations to use in the assessment. Asbestos in air concentrations measured in 2003 were also used in the assessment. The human health risk assessment was conducted using assumptions that result in an overestimate of exposure (SENES, 2003). It was concluded that human exposures to asbestos, arsenic and chromium could potentially result in an incremental lifetime cancer risk that exceeds the selected risk level of 1×10^{-5} (1 in

100,000) for the site. The SLRA included the (*conservative*) assumption that humans reside at the mine site year round, and could be potentially exposed to the contaminants three months out of a twelve month year.

Based on the results of the previous screening environmental risk assessment (RRU 1999), the 2003 Screening Level Risk Assessment (SENES 2003), and the Hazard Assessment (UMA 2004), a revised SLRA specific to human health exposure risk to airborne asbestos was undertaken in 2004. The 2004 SLRA focussed specifically on potential human health risks associated with inhalation of airborne chrysotile asbestos, which was the type of asbestos fibre mined at Clinton Creek. It was also based on the collection of site specific air quality data from 2004 not available when the 2003 SLRA was completed. The 2004 SLRA also evaluated the potential for human activity on a site-specific basis.

Hazard Assessment

The SLRA included a hazard assessment of the mine site based on the presence of chrysotile asbestos ore, the same as that mined at Clinton Creek. Asbestos (including chrysotile asbestos) is classified as a substance known to be carcinogenic by the Seventh Annual Report of Carcinogens, 1994, published by the National Toxicology Program, U.S. Department of Health and Human Services. Hazard classifications were discussed citing health information on asbestos exposure derived from studies of workers who have been exposed to asbestos in the course of their occupation. Inhalation was identified as the principal route of exposure to asbestos at the mine site.

Receptor Characterization

Receptors were identified as people who live and work in the area of the mine and can potentially be exposed to asbestos. The primary exposure pathway was identified to be inhalation of airborne fibres. At the time the SLRA was completed in 2006, it was known that there were two year-round residents and twelve part-time residents in the vicinity of the mine site. Based on information available at that time, it was understood that two of the part-time residents might eventually become year-round residents and there were a number of transient visitors to the area during the summer and late fall for fishing and hunting activities. It was also reasonable to assume that there would be a transient tourist population with the restoration of the former Forty Mile town site sometime in the future. Among the plausible site use scenarios by humans, it was determined that the potential for exposure to airborne chrysotile asbestos fibres is likely to be maximized for:

- Activities that involve disturbance of asbestos containing soils and deposits, such as walking, use of ATVs, vehicle transit, or disturbing the soils or tailings deposits at the site during remediation work,
- Individuals who spend an extended period in areas where asbestos fibres are found in soils and waste deposits, and
- Times when surface soils and asbestos-containing waste deposits are dry and when surface wind speeds are higher than average.

The concentrations of asbestos fibres in the various areas of concern were expected to be strongly influenced by meteorological conditions. It was also determined that chrysotile asbestos and its host rock tend to undergo cementation reactions when left undisturbed in surface soils, and tailings deposits may form

crusts that are resistant to wind and water erosion. These determinations are consistent with observations at the Wolverine Creek tailings pile. While it was recognized that such crusts may be subsequently disturbed by natural events such as freeze-thaw cycles and slope movements, the potential for elevated airborne concentrations of chrysotile asbestos could also increase if humans were involved in activities that disturb soils directly. Examples cited for the Clinton Creek site included extended recreational or other uses of ATVs in areas of the site with high asbestos fibre concentrations in soil. Another event that would result in elevated levels of airborne asbestos would be any regrading activities undertaken to stabilize the tailings piles.

In light of the above, the receptor of concern at the site was assumed to be individuals who may be exposed to airborne asbestos fibres for up to 30 days each year, as a result of on-site activities that have the potential to increase the concentrations of airborne fibres (for example, use of ATVs at the Mill site, or walking repeatedly across the tailings pile). This is conservatively considered as a worst-case exposure, and exposures in areas with lower soil fibre concentrations and for shorter time periods were expected to result in lower risks.

Exposure Assessment

Asbestos does not breakdown or degrade in the environment due to its physical and chemical properties. Inhalation is the principal route of exposure to asbestos and based on the 2004 air monitoring results, the maximum expected airborne fibre concentration experienced by a person at the site who is involved in activities that disturb surface soils was identified as being 0.12 fibres/ml air, at a height above ground suitable for inhalation. A lower bounds estimate of 0.02 asbestos fibres/ml air was identified.

Effects Assessment

Based on the USEPA Integrated Risk Information System that developed a chronic inhalation unit risk value for asbestos based on an additive risk of lung cancer and mesothelioma, acceptable air concentrations for a variety of incremental lifetime cancer risk levels identified in the SLRA are summarized in Table 6-1. To account for cumulative exposure via inhalation of asbestos fibres, the average airborne fibre concentration in fibres/ml is sometimes multiplied by the number of years of continuous exposure to arrive at a value of “fibres per ml year”. As an example, a worker exposed to 0.1 fibres/ml of air over a ten year period would be exposed to 1 fibre per ml year, or 1 fibre-year/ml.

Table 6-1 Risk Levels and Air Concentrations

Incremental Risk Level	Air Concentration
1 in 10,000	4×10^{-4} fibres/mL
1 in 100,000	4×10^{-5} fibres/mL
1 in 1,000,000	4×10^{-6} fibres/mL

The report cited USEPA and UK epidemiological data used to develop risk guidance for chrysotile asbestos inhalation. From this study a model was developed to determine the cumulative exposure of a human assuming that any chrysotile exposure, no matter how small or brief, will result in some increase in risk.

Risk Characterization

Using the intermittent exposures expected at the site, the incremental lifetime cancer and mesothelioma risks were calculated based on the expected site use at the former Clinton Creek Asbestos Mine. Using site specific air monitoring data (personal samples), the measured concentrations of chrysotile fibres in air (fibres/ml) were converted to measures based on cumulative exposures (fibres per ml year). Using the range of expected maximum cumulative exposure, the observed expected cancer incidence was estimated to be in the range of 1.00002 to 1.00012 equating to an incremental lifetime cancer risk (ILCR) in the range of 2×10^{-5} to 1.2×10^{-4} . It was concluded that an individual spending up to ten days at the site for a period of 8 hours/day (one year only), under weather conditions most conducive to the mobilization of asbestos fibres from soil and waste deposits to air, would have a maximum cumulative exposure of 0.00018 to 0.0011 fibres per ml year, and an ILCR in the range of 1.1×10^{-7} to 6.6×10^{-7} . These values were compared with Health Canada's assessment that cancer risks are negligible when the estimated total ILCR is less than 1×10^{-5} . A summary of the best upper-bound estimates of incremental lifetime cancer risks from airborne chrysotile asbestos at the former Clinton Creek mine site, based on 2004 conditions provided in the SLRA is shown on Figure 44.

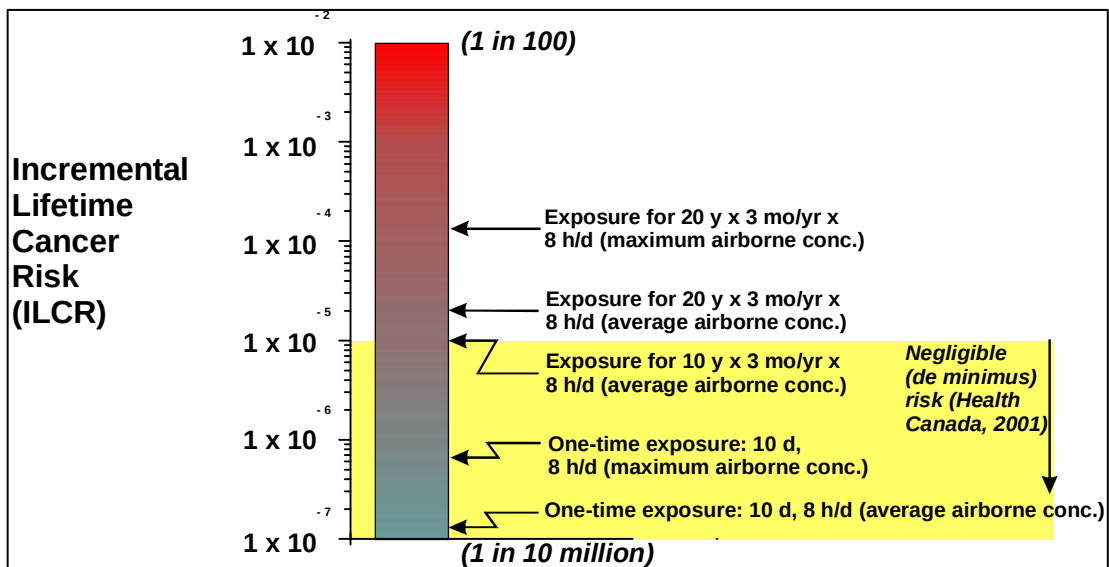


Figure 44 ILCR at Former Clinton Creek Asbestos Mine Based on 2004 Site Conditions

Since none of the epidemiological studies referenced in the SLRA report (UMA 2006) have been conducted at or near abandoned asbestos mines, there remains a possibility that the fibre lengths and particle types encountered at the Clinton Creek mine could be very different from studied occupational exposures. In

particular, the waste rock and open pit areas of the Clinton Creek site predominantly contain un-milled fibres which have not been characterized in detail. The tailings area contains fibres which are gravimetric rejects relative to the commercially viable production stream at the time of production. Fibres in the tailings area may be relatively short in their amalgamated form relative to the fibres recovered in the mill and packaged for subsequent use in a variety of products. This may or may not result in atypical airborne fibre lengths. It was concluded that the use of a single upper estimate of airborne fibre concentrations, based on the maximum measured concentration, was conservative in that it represented a large over-prediction of the airborne concentrations on most days when weather conditions are not conducive to mobilization from soils.

The assumptions regarding cumulative amount of time spent on site have a very large influence on estimates of cumulative exposures via inhalation. The assumed site use was based on the best knowledge of the site in light of current conditions at the time of the study. It was pointed out that regardless of the absolute risks, greater human use of or transit through the site will result in greater cumulative exposures. In general, it was concluded that incremental lifetime cancer risks to individual humans who visit or temporarily reside at the site fell in the range of $<1 \times 10^{-7}$ to around 1.2×10^{-4} . The highest calculated risk was related to a full time resident on the mine site property, which although was not the case at the time of the study, could change in the future. For all but highly atypical individuals who may receive exposures not anticipated as part of this screening level risk assessment, it is expected that the cancer risks associated with airborne asbestos fibres is low.

6.6.4 Identified Hazards

Asbestos fibres were widely spread across the mill site and surrounding areas in various concentrations during milling operations. Significant amounts of asbestos fibres were found during the 2003 Hazard Assessment field program at the tram line terminus building, the conveyor tunnels, on the two concrete utilidor box structures and in the area of the former dry rock building, the service building and the mill building. Air monitoring results collected from the site have indicated that human activity on the mine site can result in airborne asbestos fibres. Many of the potential hazards associated with airborne asbestos were addressed in 2004 when a hazard mitigation work program was undertaken and included some work to reduce exposure to airborne asbestos fibres. This work included:

- Blocking road access along Wolverine Creek, into Snow Shoe Pit and onto the main area of the Clinton Creek Waste Rock Dump,
- Regrading some localized areas on the Clinton Creek Waste Rock Dump having a significant amount of serpentinite rock (i.e. low grade ore),
- Covering raw asbestos fibres just north of the Porcupine Pit,
- Burying most of the asbestos ore located west of the former Crusher Building and
- Regrading much of the ground surface at the former Mill Site that was covered with tailings.

Air monitoring indicated that the remedial activities undertaken in 2004 have reduced airborne asbestos fibre concentrations. The main source of asbestos fibres remaining on the site is the tailings pile, the Wolverine Creek valley and the Snow Shoe pit. The fibres exposed in the Snow Shoe pit are typically long fibres, unlike those found at the tailings pile and along Wolverine Creek.

6.6.5 Closure Options

Continued Care and Maintenance (Status Quo)

General care and maintenance of the former Clinton Creek Asbestos Mine currently consists of blocking vehicle access at a number of locations on the site and signs posted at the mine site warning visitors to the site that asbestos fibres are present.

Soil Cover

An asbestos abatement plan to further reduce the amount of airborne asbestos at the mine site would most likely consist of placing a soil cover over remaining areas of the mine site where high concentrations of asbestos fibres exist. It would however, be likely that the tailings piles would require regrading to a more stable geometry before additional (cover) soil is added.

6.6.6 Information Gaps

Information gaps include site usage and additional monitoring of meteorological and air conditions to support the results from the SLRA and to help determine if the risk is great enough to warrant a full scale asbestos abatement plan. If placing a soil cover over the tailings pile is determined to be necessary then a geotechnical investigation and stability analysis would be required to design a regrading plan for the tailings, and a sufficient and appropriate material source would need to be identified.

6.7 Water Quality

6.7.1 Water Sampling Programs

Asbestos concentrations in water in the vicinity of the mine site were measured in 1995 and 1996 (Roach, 1998). A limited water quality evaluation was carried out in 1999 as part of an environmental review of the mine site (RRU, 1999). An additional water sampling program was undertaken by UMA in 2003 as part of an evaluation of the influence of geological conditions on the concentration of various elements in the Clinton Creek catchment, including the Porcupine and Wolverine Creek tributaries (UMA, 2004). Open pit areas, waste rock dumps, the former mine site and the tailings deposit that remain poorly vegetated were targeted as surface runoff or infiltrating water from these areas might represent a source of metals/metalloids and chrysotile asbestos fibres to Hudgeon Lake, Wolverine and Porcupine Creeks; Clinton Creek, Forty Mile River, and ultimately the Yukon River. The samples collected in 2003 were not tested for asbestos fibres since the previously collected data from 1999 provided an indication of the range of fibre concentrations found downstream of the mine (RRU, 1999).

Analytical Results

The water samples were analyzed for anions, nutrients, and metals/metalloids and compared to British Columbia Approved Water Quality Guidelines for Freshwater Life Protection (where no CCME Aquatic Life

Guidelines currently exist) or the relevant Canadian Council of Ministers of the Environment (CCME) Guidelines. The water sample results provided some insight as to the influence of local geological conditions on concentrations of various elements in the Clinton Creek catchment area. All local water bodies exhibited high sulfate levels with the highest levels in the Porcupine Pit. The elevated sulfate in Porcupine Pit water was thought to be possibly due to enhanced solubilization from magnesium sulfate minerals. For Wolverine Creek and upper Clinton Creek, the elevated sulfate concentrations appeared to be based on background mineralization, with no apparent additional contribution from mine area runoff. The influence on the Clinton Creek watershed from sulfate inputs from Porcupine Creek appeared to be minimal due to the substantial dilution of Porcupine Creek water as it enters Clinton Creek. Samples from Mickey Creek and the Forty Mile River upriver from the Clinton Creek inflow exhibited low sulfate concentrations.

Neither nickel nor chromium appeared to be liberated to the water, an observation consistent with leachability tests on serpentinite or other asbestos bearing materials (UMA, 2006). With the exception of chrysotile asbestos fibres and sediment in the Wolverine Creek drainage (and subsequently in Clinton Creek and then Forty Mile River) water quality did not appear to be affected by surface drainage from the tailings pile and mill site area.

The Porcupine Creek drainage just upstream from where it enters Clinton Creek had elevated levels of arsenic and sulfate relative to the other sampling locations. The source of these was believed due to local geological conditions, although the extent to which the pit and waste rock exacerbate dissolution and release from the geological source material could not be determined (no upstream reference samples were taken). Regardless, it was determined that dilution of the Porcupine Creek inflow once it joins the Clinton Creek flows results in arsenic concentrations lower than water quality guidelines for the protection of aquatic life.

The single Porcupine Pit sample collected revealed elevated levels of antimony, boron, and a large number of other cations or other metal species. This sample had a different composition than the Porcupine Creek samples, indicating there may be unique geochemical processes (or concentration of substances as a result of evapotranspiration) occurring in the water ponded in the pit relative to the larger watershed. Elevated boron and antimony levels within the Porcupine Pit did not appear to have influenced water quality in Clinton Creek.

6.7.2 Hudgeon Lake Water Quality

Hudgeon Lake is permanently anoxic (depleted of oxygen) in its bottom waters. Based on data collected by Werner Liebau (INAC), the anoxia during open water periods extends from the lakebed (maximum depth of approximately 27 m) to within approximately 5 m of the surface or less. The lake bottom consists of former terrestrial vegetated areas that were inundated following the blockage of the Clinton Creek valley by mine waste rock. As such, Hudgeon Lake contains large amounts of woody debris and other organic materials that can decompose on the lake bottom in the presence of elevated sulfate levels (believed to be naturally occurring) and in a limited oxygen supply thought due to the limited capacity of inflowing water to replenish oxygen at depth in the lake. In this environment, the sulfates are reduced into highly toxic sulfides. It appears sulfide levels in downstream areas are acceptably low and oxygen levels sufficiently high (DFO, 2007). Re-oxygenation would occur at and immediately beyond the outlet of Hudgeon Lake to re-convert S^{2-}

to SO_4^{2-} , and to off-gas any residual H_2S . The four gabion drop structures likely contribute to the re-oxygenation of water leaving Hudgeon Lake.

Elevated cadmium and iron in surface water samples from Hudgeon Lake were also detected. Elevated iron in Clinton Creek as far downstream as the Forty Mile River was considered to be associated with severely anoxic conditions in Hudgeon Lake. The overall interpretation for cadmium was less clear, however, since the Eagle Creek sample chosen as a reference sample from an unaffected tributary, had a similar cadmium concentration to the Hudgeon Lake and upper Clinton Creek samples. Although the analytical detection limits for cadmium for some samples were too high to draw any firm conclusions, the presence of cadmium in Eagle Creek suggests naturally elevated concentrations. All cadmium results were lower than the Canadian drinking water guidelines of 0.005 mg/L, so it is concluded that there are no human health risks associated with cadmium in surface waters from the Clinton Creek watershed.

6.7.3 Role of Different Minerals in Metal / Metalloid Release to Surface Waters

The leachability of different minerals/waste materials at the Clinton Creek Mine site was evaluated based on collection of seven representative samples collected by Government of Yukon staff in the vicinity of Hudgeon Lake, the channel stabilization works in Clinton Creek and the tailings pile. These mineral/waste material samples were analyzed for 36 elements by digestion followed leachability testing based on the modified Special Waste Extraction Procedure (SWEP), and acid-base accounting (ABA) analysis. The SWEP is designed to assess mobilization into water under conditions similar to or worse than might be encountered in the environment (based on pH).

As expected, the quartz-carbonate altered serpentinite exhibited naturally elevated levels of arsenic, antimony, barium, boron, chromium, cobalt, mercury, nickel, and magnesium. Cadmium was not detected in the serpentinite samples, but was detected in two samples of argillite. One of the tailings samples had a very high concentration of boron relative to the other samples. Overall, the SWEP results confirmed that the Clinton Creek waste rock materials (i.e. argillite) have very limited leachability. Serpentinite soils exhibited a higher concentration of leachable arsenic and antimony than argillite samples. Cadmium was not leached from either the argillite or serpentinite samples under the extraction conditions used. This further suggested that the cadmium in Hudgeon Lake surface waters is released from argillite-type minerals, but only under reduced conditions. The results of acid-base-accounting (ABA) trials indicated that the host rock (i.e. serpentinite) and waste rock (i.e. argillite) contains only small amounts of sulfide minerals (related to acid generating potential) and sulfate relative to the large neutralization potential. As expected, there was no potential for acidic rock drainage from the argillite material forming the waste rock dumps.

6.7.4 Asbestos in Water and Sediments

Chrysotile asbestos was detected in water and sediment samples from Hudgeon Lake, Wolverine Creek and Clinton Creek and compared with background concentrations. Chrysotile asbestos concentrations in Hudgeon Lake sediments ranged from 1 to 5 percent which are comparable to concentrations in the waste rock dump material. Fibre concentrations in Hudgeon Lake water ranged from less than 1×10^6 to as high as 112.73×10^6 fibres/litre confirming previous (1995) results and the potential for release of asbestos fibres from the waste rock into Hudgeon Lake exists. Similar observations were made in Wolverine Creek sediments in the pond between the north and south lobes where asbestos concentrations ranged from 3 to

10 percent. Asbestos fibre concentrations in the pond water ranged from 9.66×10^6 to 22.62×10^6 fibres/litre which were comparable to samples collected from the pond in 1996. The highest concentration of asbestos in Clinton Creek sediments (3-5%) was measured at the confluence of Wolverine Creek. Concentrations in sediments downstream of this location were either close to or below the detection limit. The concentrations of asbestos fibres in Clinton Creek water ranged from 1.07×10^6 to 152.45×10^6 fibres/litre at the town site ford crossing. The high level at the ford crossing was considered unusual and did not agree with a concentration of 1.20×10^6 fibres/litre measured at the same location in 1996 (Roach, 1998).

Asbestos concentrations in the Forty Mile River above and below Clinton Creek and the Yukon River below the Forty Mile River were measured in 1996 (Roach, 1998). These results appeared to indicate that asbestos fibre concentrations are influenced to some degree by what is discharged from Clinton Creek. It also was observed however, that there was asbestos in both the Forty Mile and Yukon Rivers upstream of Clinton Creek. Additional sampling within the Whitehorse watershed in 1996 and 1997 further confirmed the presence of chrysotile asbestos fibres in many rivers not associated with Clinton Creek ranging from non-detect to 13.41×10^6 fibres/litre.

6.7.5 Information Gaps

The effects on aquatic life of water-borne chrysotile asbestos is not well addressed in scientific literature. A 1978 environmental assessment of the effects of asbestos in water at the Clinton Creek Mine Site by the Department of Environment, Environmental Protection Service (Pacific Region) concluded that significant adverse effects on the invertebrate communities and fish populations as a result of substrate alteration and the presence of asbestos fibres (DOE, 1978). A subsequent study by Royal Roads University determined that the 1978 report was inconclusive for stream invertebrates (personal communication, Dr. D. Bright). In any case, there is an identified information gap with respect to the possible effects on fish or other freshwater biota from water borne asbestos fibres. YG-AAM is currently undertaking a review of available information in this area. There is some uncertainty as to the fate and perseverance of cadmium in water. YG-AAM is currently reviewing the available data on water and sediment quality for the site with the intention of identifying and addressing any relevant unknowns.

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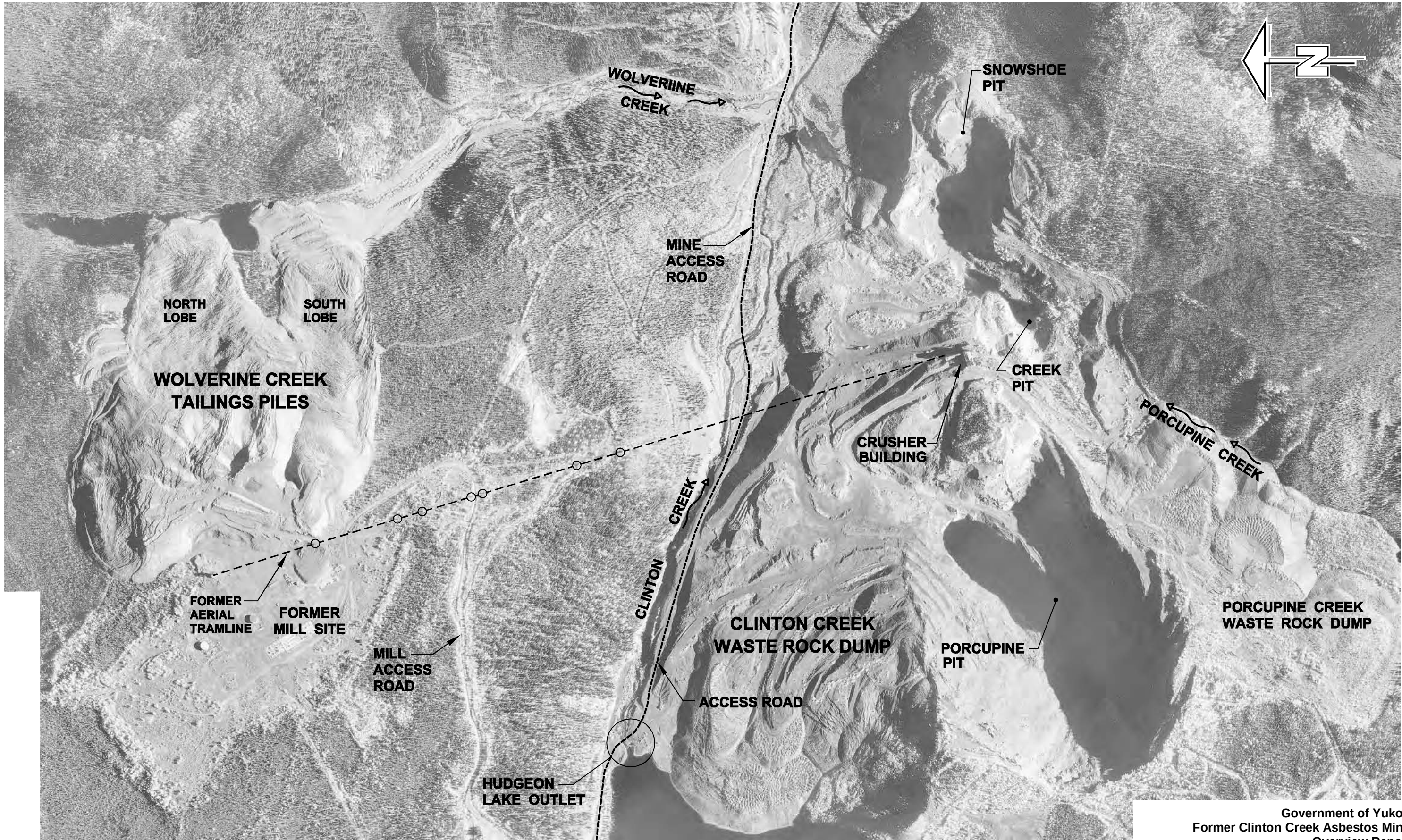
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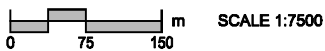
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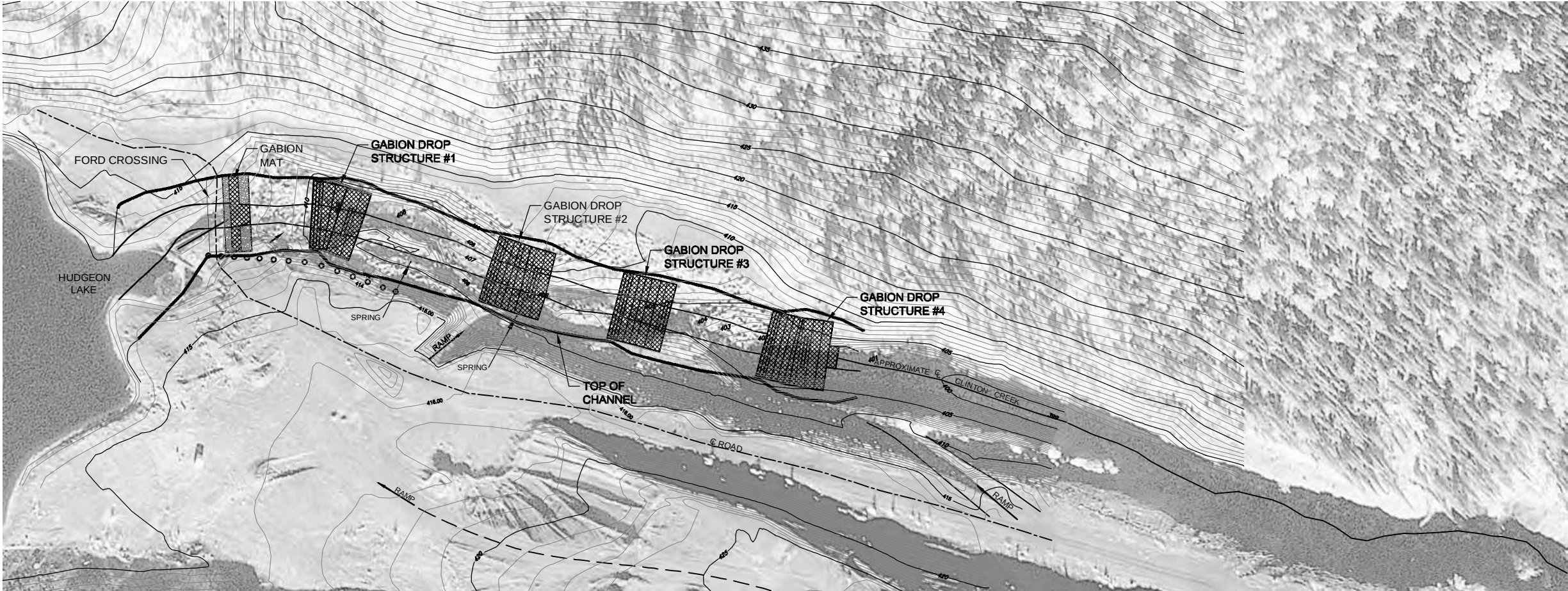
Drawings



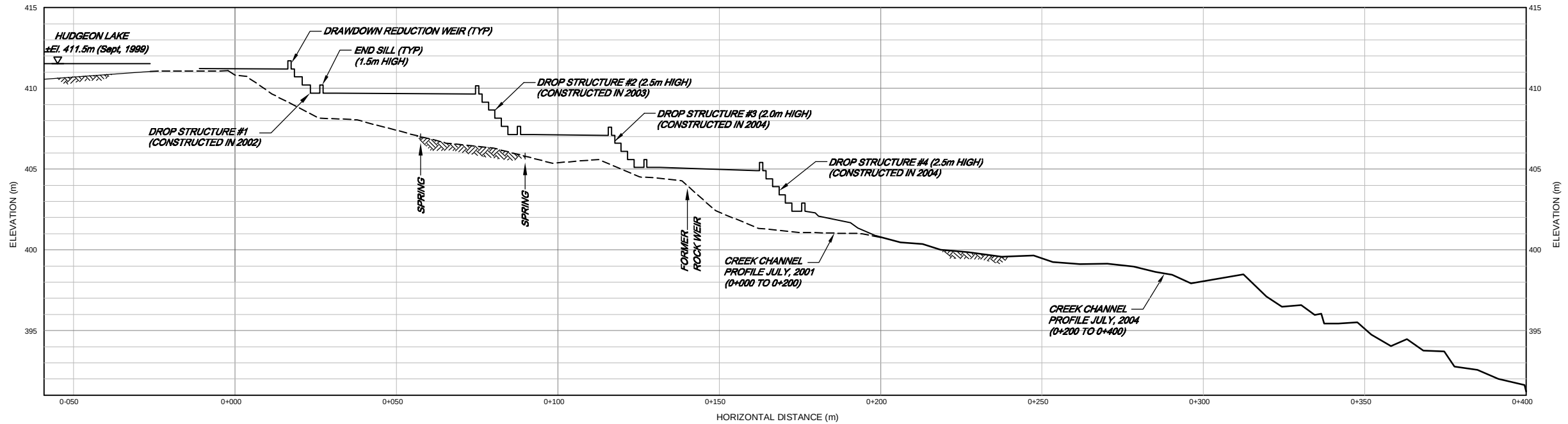
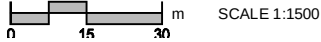
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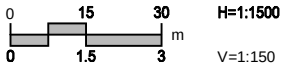
Government of Yukon
Former Clinton Creek Asbestos Mine
Overview Report
Mine Site Plan



CLINTON CREEK CHANNEL



CLINTON CREEK CHANNEL PROFILE



Appendix A

Summary of Hazard Mitigation Measures

SUMMARY OF HAZARD MITIGATION MEASURES

Location	Description of Identified Hazard		Mitigation Measures Completed In 2004	Mitigation Measures Since 2004
OPEN PITS				
Porcupine Pit	Slope Failure	Recent slide on SE side of pit wall.	Both access roads onto waste rock pile blocked and earth berm used to block road past former crusher building location.	Signage posted. Ditch and berm constructed around southern and western sides of Porcupine pit
Porcupine Pit	Slump Block on West Corner of Pit	Ground has dropped 10 - 15m into open pit.	Both access roads onto waste rock pile blocked and earth berm used to block road past former crusher building location.	
Porcupine Pit	Head Scarp	Head scarp for slump block into NW side of open pit.	Both access roads onto waste rock pile blocked and earth berm used to block road past former crusher building location.	
Porcupine Pit	Head Scarp	Head scarp for slump block into NW side of open pit. Scarp 23m high. Evidence of recent movements. Also multiple slump blocks on waste rock dump side.	Both access roads onto waste rock pile blocked and earth berm used to block road past former crusher building location.	
Porcupine Pit	Head Scarp	Pit wall unstable with recent movement into open pit. Also movement towards waste rock dump.	Both access roads onto waste rock pile blocked and earth berm used to block road past former crusher building location.	
Porcupine Pit	Slope Failure	Head scarp and recent slump blocks with movement into open pit.	Both access roads onto waste rock pile blocked and earth berm used to block road past former crusher building location.	
Porcupine Pit	Raw asbestos ore	Asbestos fibres on ground over 50 X 50m area.	Both access roads onto waste rock pile blocked to restrict access. Ore covered with waste rock material. Air monitoring conducted before and after ore covered.	
Creek Pit	Raw asbestos ore	Asbestos fibres behind windrow of boulders. Area about 20 X 20m. Also 20 X 50m area on E side of boulders.	Access road to Creek Pit blocked. Air monitoring conducted in the adjacent Snow Shoe Pit.	
Creek Pit	Tension Cracks	Evidence of recent slumping and 25mm wide tension cracks.	Access road to Creek Pit blocked.	Signage posted.
Creek Pit	Open Pit	Pit wall unstable with evidence of recent debris /rock fall on W side near crusher. Area may be used for swimming.	Access road to Creek Pit blocked.	
Snowshoe Pit	Pit Wall Slide	Start of Slide on S side of open pit. Slumping and tension cracks are visible on benches above slide.	Access road blocked.	
Snowshoe Pit	Raw asbestos ore	Thick layer of asbestos fibre on flat area above main pit.	Access road blocked. Air monitoring completed. Screening level risk assessment completed.	
WASTE ROCK DUMPS				
Porcupine. Cr. Waste Rock	Partially Buried Debris	Truck chassis, barrels, cable spool on slope.		
TAILINGS PILE AND WOLVERINE CREEK				
Tailings Pile (near Mill Site)	Partially Buried Debris	Metal debris: Drums, structural steel, boiler, bicycle frame, hot water tank, tires, wire, milled asbestos samples	Air monitoring completed and screening level risk assessment completed. Additional work to be defined.	
Tailings Pile & Wolverine Creek	Asbestos: Tailings pile and deposits in Wolverine Creek.	Potential for generation of fugitive asbestos dust and exposure to site users on tailings pile and along Wolverine creek.	Tailings pile monitored and report prepared. Air monitoring completed and screening level risk assessment completed. Additional work to be defined.	
Tailings Pile	Tension Cracks	100mm wide tension cracks in road to top of S Lobe. Recent movement towards ravine between lobes.		Performance monitoring is ongoing. Trigger levels have been established for remedial action.
Tailings Pile (near Mill Site)	Partially Buried Debris	Structural steel from conveyor supports protruding from cover.	Cut 600mm below grade and backfilled.	
CRUSHER BUILDING				
Crusher Bldg.	Tension Cracks and Asbestos Fibres	Tension cracks in area 50m west of crusher building. Evidence of settling, slope movement. 200mm thick layer of asbestos fibres covering the area.	Pit area regraded and air monitoring conducted before and after the regrading work. The general area, about 100m x 100m, still has raw asbestos fibres mixed with soil. Access roads to this area of the mine are blocked. Screening level risk assessment completed.	

SUMMARY OF HAZARD MITIGATION MEASURES

Location	Description of Identified Hazard		Mitigation Measures Completed In 2004	Mitigation Measures Since 2004
Crusher Bldg.	Crusher Building / Tramway (Towers #1 and #2)	Crusher Building. Warped structural elements (beams from fire inside ore bucket maintenance area). Unsecured sheet metal siding, numerous climbing/fall hazards, significant mounds of asbestos in and around building. Loosely hanging ore buckets. Tram Tower #1 in-place. Tram tower #2 removed.	Crusher building and tram towers demolished. Building foundations backfilled. Demolition material stockpiled near old mining equipment. Public access via walking or possibly ATV only. Low rating due to steep slopes in the area.	Demolition waste salvaged or buried in on-site landfill
Crusher Building	Surface Debris	Metal debris along E side of road into crusher.	Debris moved to demolition material stockpile.	Metal hopper demolished. Demolition waste salvaged or buried in on-site landfill
TRAMWAY				
Tramway	Tram Tower	Tram Tower #3: Large concrete structure for first tram tower on north side of Clinton creek. Large mound of asbestos ore 5m deep over 20m x 20m area on south side of structure. Ladder rungs on north side of structure accessing superstructure.	Ladder rungs cut off concrete tower pier. Area is not visible from mill site road.	Demolition waste salvaged or buried in on-site landfill
Tramway	Tram Tower	Tram Tower #4. Erosion of soil around W side of concrete base. 0.5m layer of asbestos fibres for 30m S of tower. Ladder accessing timber platform.	Tower removed and stockpiled with other demolition debris near old mining equipment. Foundation demolished and backfilled.	
Tramway	Tram Tower	Tram Tower #5. Asbestos fibres in area. Ladder accessing timber platform. Wood pole laying down beside tower.	Tower removed and stockpiled with other demolition debris near old mining equipment. Foundation demolished and backfilled.	
Tramway	Tram Tower	Tram Tower #6. Asbestos fibres in area. Ladder accessing timber platform. Minor concrete deterioration. Tower adjacent to mill road.	Tower removed and stockpiled with other demolition debris near old mining equipment. Foundation demolished and backfilled.	
Tramway	Tram Tower	Tram Tower #7. Mound of asbestos fibres between tower and road. Ladder accessing timber platform.	Tower removed and stockpiled with other demolition debris near old mining equipment. Foundation demolished and backfilled.	
Tramway	Tram Tower	Tram Tower #8. 300mm of asbestos fibres on S side of tower. Wood pole laying down beside tower. Ladder accessing timber platform.	Tower removed and stockpiled with other demolition debris near old mining equipment. Foundation demolished and backfilled.	
Tramway	Tram Tower	Tram Tower #9. Tram cable on ground. Asbestos fibres: 75mm layer, 2m wide, 10m long S of tower. More fibre between Tower 9 and 8. Wood pole laying down beside tower. Ladder accessing timber platform.	Tower removed and stockpiled with other demolition debris near old mining equipment. Foundation demolished and backfilled.	
Tramway	Tram Tower	Tram Tower #10. Power cable and tram cable on ground. Wood pole laying down beside tower. Asbestos fibre on ground around tower. Ladder accessing timber platform.	Tower removed and stockpiled with other demolition debris near old mining equipment. Foundation demolished and backfilled.	
Tramway (Mill Area)	Tram Tower	Tram Tower #11. Pipe supports cut 150mm above concrete pad. Asbestos fibres in immediate area.	Cut pipe flush with concrete, backfill around concrete base and fill in tower pipe holes. Cover asbestos fibres.	
Tramway (Mill Area)	Tram Tower	Tram Tower #12 partially buried in 50mm mill overs.	Tower cut down to 500mm below grade and backfilled.	
Tramway (Mill Area)	Tram Terminus Structure	Surface debris scattered in area with significant tailings and asbestos. Building in poor condition and contains corrugated asbestos board, steel debris and tram drive transmission and brake. Roof heavily covered with asbestos dust. Hydrocarbon staining on floor. Ladder access to top of steel structure.	Building and steel tram structure demolished. Steel stockpiled with other demolition materials near the old mining equipment. Concrete Footings backfilled with local borrow material.	
Tramway	Former power line	Power line poles laying down beside tram towers 3 to 10 on north side of Clinton creek.		
MILL AREA				
Mill Area (Utilidor)	Former office building - east side, 2 storey concrete structure.	4m X 4m structure, top floor empty, basement contains cast iron pipe, galvanized pipe, duct work and wood debris. 2.3m deep pit in NE corner is open and contains pipes that head through connecting utilidor tunnel towards mill site	Building demolished and backfilled with local borrow material.	

SUMMARY OF HAZARD MITIGATION MEASURES

Location	Description of Identified Hazard		Mitigation Measures Completed In 2004	Mitigation Measures Since 2004
Mill Area (Utilidor)	Boiler plate utilidor manhole	1.2m diam., 3.2m deep shaft containing pipe from concrete structure (Photo 329) and tunnel to mill site. 12mm thick plywood cover (not secured). Fibreglass and asbestos pipe insulation.	Manhole backfilled with local borrow material.	
Mill Area (Utilidor)	Former Service Building: Concrete foundation with utilidor tunnel at SE end.	SW corner of foundation has open pit with tunnel connecting to Feature 16 and smaller shaft to N (also open). Shaft opening is 0.6m x 0.6m and is 3m deep. Smaller shaft has 0.6m x 0.6m opening and is 2.5m deep. Mounded area on outside of corner may be backfill for another shaft. Considerable corrugated asbestos board in area.	Pit backfilled with local borrow material.	
Mill Area (Utilidor)	Utilidor access structure.	Concrete structure 2.5m x 5m and 1m above grade. Access hatch in corner uncovered with metal rungs to bottom of structure at 3m deep. Asbestos fibres in and around structure.	Concrete structure demolished to at least 500mm below grade and backfilled. Asbestos fibres in surrounding area covered with local borrow.	
Mill Area (Utilidor)	Utilidor access structure.	Concrete structure 2.9m x 4.2m and 1m above grade. Access hatch in corner uncovered with metal rungs to bottom of structure at 3m deep. Asbestos fibres in and around structure.	Concrete structure demolished to at least 500mm below grade and backfilled. Asbestos fibres in surrounding area covered with local borrow.	
Mill Area (Utilidor)	Utilidor access structure. - Discovered in 2004.	Concrete structure 2.9m x 4.2m with roof at groundsurface. Access hatch in corner uncovered with metal rungs to bottom of structure at 3m deep. Asbestos fibres in and around structure.	Concrete structure roof demolished and remaining void backfilled.	
Mill Area	Water Storage Tank and water pump house foundation.	White water storage tank (V ~ 1.4 Million litres) with concrete foundation on SE side which is partially backfilled (opening to utilidor). Pipes from utilidor protruding from within the foundation (Photo 349). Ladder on SW side of tank has rusted attachments to tank. Pipe and structural steel protrude from tank. Roof of tank is rusted, 1 corrosion hole visible.	Tank demolished and stored with other demolition material near old mining equipment. Foundations backfilled.	Demolition waste salvaged or buried in on-site landfill
Mill Area	Fuel Storage Tank	Blue fuel storage tank: V ~ 1.4 Million litres. 5m X 5m foundation and concrete slab with 0.6m grade beam on S side of tanks, likely from former pump house. Tank has an earth berm around the perimeter, ladder to roof and buried pipes on W side. Entrance hatch on SW side open where tank can be entered. Hatch on roof also open. Slight hydrocarbon odour detected at hatches.	Tank demolished and stored with other demolition material near old mining equipment.	
Mill Area	Conveyor Tunnel #1 From Dryer Building	Opening 40m from entrance. Exterior and interior contains significant asbestos dust. Lower end of conveyor tunnel has been poorly backfilled with tailings.	Concrete tunnel demolished to at least 500mm below grade and backfilled with local borrow material. Asbestos fibres in local vicinity covered.	Spring 2008: a short section of one of the old conveyor tunnels had a backfill cave in and the backfill was topped off. The site is inspected several times a year to check for similar occurrences
Mill Area	Conveyor Tunnel #2: dry rock storage to mill.	Entrance damaged with large concrete piece hanging by reinforcing steel. Numerous pieces of protruding reinforcing steel. Tunnel has up to 0.2m of asbestos dust. Part of conveyor visible in tunnel. Bottom end of tunnel filled with water at about 25m from entrance.	Concrete tunnel demolished to at least 500mm below grade and backfilled with local borrow material. Asbestos fibres in local vicinity covered.	
Mill Area	Conveyor Tunnel #2: dry rock storage to mill.	Depression in ground coincident with opening to conveyor tunnel about 45m from entrance. This was the location where dry rock was loaded on to the conveyor. Opening was partially backfilled, small void and steel support visible at surface (Photo 361). Equipment still inside tunnel includes: catwalk, conveyor, dust control piping. Void leads to water filled tunnel with pipes, ramps and stairs visible. Confirmed this is connected to conveyor tunnel.	Concrete tunnel demolished to at least 500mm below grade and backfilled with local borrow material. Asbestos fibres in local vicinity covered. Equipment inside tunnel was frozen in 600mm of ice, left in place and backfilled.	

SUMMARY OF HAZARD MITIGATION MEASURES

Location	Description of Identified Hazard		Mitigation Measures Completed In 2004	Mitigation Measures Since 2004
Mill Area	Former Dry Rock Storage Building	Partially buried metal, concrete and wood debris with significant asbestos fibre/dust in area. Depression may have been a result of removing concrete floor and sub-floor conveyors.	Sub-floor conveyors removed previously.	
Mill Area	Former Dry Rock Storage Building	Depression in ground surface over footprint of former building. Concrete rubble with voids. Depression may have been a result of removing concrete floor and sub-floor conveyors.	Sub-floor conveyors removed previously.	
Mill Area	Concrete footing.	3m x 6m concrete slab with exposed re-bars and covered with asbestos.	Work for 2005: Cut-off rebar.	GY advised that 2005 work was completed
Mill Area	Former Mill Building: Concrete Structure	Deteriorated structure with steel chutes attached to underside. Deteriorated concrete and exposed re-bars.	Removed overhanging steel chutes. Work for 2005: Remove loose concrete and exposed, protruding re-bar.	
Mill Area	Former Service Building: Concrete foundation with pits.	Pits in NW corner of concrete slab. One pit 0.5m x 5m by 2m deep. Second pit 1m x 10m is filled with debris including asbestos board.	Backfilled openings with local backfill material.	
Mill Area	Surface Debris	Asbestos tailings over 50m x 50m area. Also, galvanized metal couplers for 1.2m CSP.	Air monitoring and soil samples collected. Screening level risk assessment completed.	
Mill Area	Partially Buried Debris	Area covered with 50mm mill overs and tailings. Also, steel pipe, asbestos board.	Air monitoring and soil samples collected. Screening level risk assessment completed.	
Mill Area	Asbestos Tailings	General area covered with asbestos tailings.	Air monitoring and soil samples collected. Screening level risk assessment completed.	
Mill Area	Former office building: concrete footing	3m long, partly buried with exposed reinforcing steel	Demolished and backfilled with local borrow materials.	
Mill Area	Former office building: concrete grade beam.	20m long, partly buried with exposed reinforcing steel	Demolished and backfilled with local borrow materials.	
Mill Area	Wood Box Culvert	Partially collapsed	Excavate and backfill culvert.	
Mill Area	Shaft and Partially Buried Debris	25 X 30m mounded area with 1m diam. by 1m deep open CMP at SE corner with 50mm pipe spanning top. This may be part of the water supply system, may lead to water tank or old office building. Also vehicle wheel visible in cover (remainder of cover good)	Backfill CMP.	
Mill Area	Partially Buried Debris	Metal & Wood Debris: Truck chassis, misc wood, galvanized metal culverts, barrels		
Mill Area	Surface Debris	16 - 6m long cast iron pipes		
Mill Area	Surface Debris	6- 10m long pieces of reinforcing steel, misc wood		
Mill Area	Partially Buried Debris	Debris over slope includes wood, wire, galvanized pipe, asbestos board		
Mill Area	Former office building - west side, 2 storey concrete structure.	4m X 4m structure, both floors empty, misc wood and metal debris scattered in area	Building demolished and backfilled with local borrow material.	
Mill Area	Former Mill & Dryer Building: Concrete Foundations	Misc concrete footings and structures. Walls up to 1m thick. Concrete in good condition. Total volume about 60 cubic metres		
Mill Area	Partially Buried Debris	Structural steel protruding from pile of 50mm mill overs.		
Mill Area	Tension Cracks and Asbestos Fibres	Metal debris in NE corner of 20 X 20 X 2m high gravel pad		
Mill Area	Surface Debris	Includes pipe, wood, car, tram cable and heavy equipment parts in bush area.		
Mill Area	Surface Debris	Debris in cleared area includes rope, guy anchor, wood, steel strapping covered by thin layer of asbestos dust		

SUMMARY OF HAZARD MITIGATION MEASURES

Location	Description of Identified Hazard		Mitigation Measures Completed In 2004	Mitigation Measures Since 2004
Mill Area	Wood Poles	7m long treated (creosote)		
Mill Area	Surface Debris and Partially Buried Debris	Tram cable & wood located in bush on S side of clearing. Barrel with black solidified contents (spilled on ground- Photo 374). Debris extends along entire edge of clearing.		
Mill Area	Partially Buried Debris	Darkish brown debris further back along edge of clearing. Metal debris also extends into pad.		
Mill Area	Surface and Partially Buried Debris	Heavy equipment including shovel bucket and arm, large steel and timber skid, earth scraper. Also tram cable on wood spool.		
Mill Area	Partially Buried Debris	Small amount of metal debris along cut line.		
Mill Area	Partially Buried Debris	8 to 10 half sections of 1.2m diam. CMP, also asbestos board, wood and plastic pipe.		
Mill Area	Surface Debris	50 X 75m gravel pad with pieces of wood foundation (untreated), scattered metal and battery (Photo 382) fragments.		
Mill Area	Partially Buried Debris	30 X 30m mounded area with wood, cast iron pipe, wire, power cable. Suspect wood poles buried here as well.		
Mill Area	Partially Buried Debris	Includes untreated wood, metal in backfill at up gradient end of 2.5m deep, 50m long channel. 3 power lines run parallel to channel along alignment to former Hudgeon Lake water intake.		
Mill Area	Partially Buried Debris	Series of 3 - 4m high mounds with scattered debris around perimeters and partially buried wood stave pipe.		
Mill Area	Surface and Partially Buried Debris	Surface debris against tailings pile includes galvanized metal siding, asbestos board and wood. Partially buried metal debris also visible.		
Mill Area	Partially Buried Debris	Partially buried metal in tailings pile, approx 10m x 50m x 3m high. Includes barrels and strapping.		
Mill Area	Former fibre storage building- concrete foundation	Slab on grade with 1.7m high knee walls.		
Mill Area	Transformer pad	1 X 1m concrete base with fence posts around. Barbed wire attached to top of posts but chain link is missing.		
ANFO STORAGE FACILITY				
ANFO Facility	Fertilizer storage tank	ANFO storage tank: (V ~ 1.4 million litres) Unloading conveyor, hopper and loading conveyor. Tank is badly corroded with some fertilizer remaining in bottom (V~150m ³). Four creosote poles and wooden stairs (rotten).	Demolished tank, conveyors & tank loading facility. Demolition material stockpiled near old mining equipment. Slopes flattened and remaining ammonium nitrate spreadout and buried. Access road ripped with dozer to promote vegetation growth and road access blocked at former crusher building location.	Demolition waste salvaged or buried in on-site landfill
ANFO Facility	Former building site	Two buildings visible on 1976 air photos but not on the 1999 air photos.	No hazards identified. Buildings demolished previously.	
ANFO Facility	Scattered Surface Debris	Scattered wood debris on raised gravel pad about 20mx 50m x 1.2m high.	Debris moved to demolition material stockpile.	Debris removed and buried in on-site landfill
MISCELLANEOUS				
200m north of former Crusher Bldg.	Stockpiled Demolition Materials	Demolition material: sharp edges, loosely stacked and some items coated with asbestos fibres. Vehicle access to area is blocked.	Future Work: Demolition materials should be landfilled and/or salvaged.	Salvage and landfilling work completed by others under Contract with Government Of Yukon.

SUMMARY OF HAZARD MITIGATION MEASURES

Location	Description of Identified Hazard		Mitigation Measures Completed In 2004	Mitigation Measures Since 2004
Hudgeon Lake	Former Water Intake	2 untreated wood poles in Hudgeon Lake, hydro lines in water, wooden stairs, misc scattered wood and metal debris.	Wooden stairs demolished. Future Work: Remove Poles and power lines from water	Poles and power lines still in place.
200m north of Crusher Bldg.	Heavy Equipment	Drill and shovel. Drill has electrostatic precipitator with asbestos laden filters. Shovel may contain transformer oil.	Future Work: Sample and test transformer fluid from drill. Recover fluid after contents verified. Remove and landfill air filters on drill. Options for equipment include: salvage or landfilling.	Drill and shovel remain on site. Transformer fluid do not contain PCB's. Fluids not yet drained, air filters not yet removed.
Creek Pit	Steel Frame	Tubular steel frame across road to pit. May have been for service/inspection. Can be climbed.	Frame moved to demolition materials storage area near the old mining equipment.	Demolition waste salvaged or buried in on-site landfill
Creek Pit	Small wooden shelter	Plywood structure in poor condition.	Demolished.	
Easter Creek	Former Water Intake	Original water intake on Easter Creek: timber cribbing on creek banks, remnants of pipe insulation and wood supports on valley slope		