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GOVERNMENT OF YUKON
FORMER CLINTON CREEK ASBESTOS MINE - SUMMARY OF 2004 HAZARD MITIGATION WORK, MONITORING AND A SCREENING LEVEL RISK ASSESSMENT FOR AIRBORNE ASBESTOS

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March 14, 2006 UMA Project No. 6029 006 01 (4.6.1)

Mr. Hugh Copland, P.Eng., P.Geo.
Government of Yukon - Energy, Mines and Resources
Box 2703 (K-419)
Whitehorse, Yukon
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Dear Sir:

Reference **Former Clinton Creek Asbestos Mine – Summary of 2004 Hazard Mitigation Work, Monitoring and a Screening Level Risk Assessment For Airborne Asbestos**

Enclosed please find UMA's evaluation of human health and safety issues at the former Clinton Creek Asbestos Mine, Yukon. This report includes an update of physical hazards based on hazard mitigation work completed up to the end of 2004, a summary of the monitoring program results from 2003 and 2004 as well as a screening level human health risk assessment based on the potential for inhalation of asbestiform fibres by people who may visit the mine site.

If we can be of further assistance, please contact Gil Robinson.

Sincerely,

UMA Engineering Ltd.

R. J. Typliski

Ron Typliski, P.Eng.
Regional Vice President
GR/dh

Table of Contents

List of Figures

List of Tables

Drawings

Photographs

List of Appendices

1.0 Introduction and Background

1.1 Introduction

This report provides 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 includes 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.

In 2003, a hazard assessment program (UMA 2004) was carried out at the former Clinton Creek Asbestos Mine to identify and classify human health and safety hazards at the mine site and provide recommendations for potential corrective (i.e. risk mitigation) measures. Previous investigations at the mine site include an environmental review (RRU 1999), a screening level risk assessment (SENES 2003) and reviews of 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 (UMA 2000, 2002 and 2003). This report summarizes the work undertaken at the mine site in 2004.

In addition to the evaluation of physical site hazards in the Hazard Assessment Report (UMA 2004), the risks to aquatic or terrestrial life of metals mobility for mine wastes have been evaluated to some extent (i.e., based on a preliminary environmental risk assessment). Royal Roads University (1999) in collaboration with UMA, and with the assistance of Indian and Northern Affairs Canada, Waste Management, undertook aquatic (minnow traps, gillnetting, electrofishing, invertebrate drift samples, plankton samples) and terrestrial (ground cover surveys) habitat evaluations. The potential for mobilization of metals from the serpentinite-type and argillite waste rock or tailings was examined based on field sampling of water, sediment and soil. Follow-up investigations were undertaken in 2003 during the hazard assessment program (UMA 2004).

Overall, it was concluded that metals such as arsenic, barium, chromium and nickel are naturally elevated in soils and the watershed within the region, and the further introduction of mine-related metals or asbestiform fibres into the surrounding environment is unlikely to result in unacceptable risks to terrestrial and aquatic species.

In 2003, SENES undertook a "Screening Level Risk Assessment" (SLRA) of the former Clinton Creek mine site and a larger number of other northern contaminated sites, using expedited preliminary environmental risk assessment methods adopted to assist with the Federal Contaminated Sites Accelerated Action Program. Quantitative estimates of human health risks were derived for carcinogens and non-carcinogens, with a focus on metals in soils (antimony, barium, chromium, nickel); however, the risk assessment did not account for realistic estimates of human site use, nor of the limited bioavailability of the metals of concern from serpentine soils and tailings material. Risk estimates for humans from airborne asbestos fibre inhalation were based on a limited dataset from air monitoring.

The main concern for human health risks at this former mine site is undoubtedly in association with the potential for inhalation of airborne fibres of chrysotile asbestos by individuals who might be working at various areas of the site, infrequently visiting the site, and/or transiting the site by foot, vehicle or ATV.

With respect to the potential for a catastrophic breach of the Clinton Creek waste rock dump at the Hudgeon lake outlet, creek stabilization work has been undertaken in this area and the risk of a breach has been mitigated (UMA 2003a, 2003b, 2005). The consequences of a breach and rapid draining of Hudgeon Lake are discussed in UMA's Risk Assessment Report (UMA 2000)

1.2 Background

The former Clinton Creek Asbestos Mine is located about 100 km northwest of Dawson City in the Yukon Territory, 9 km upstream of the confluence of Clinton Creek and the Forty Mile River. The mine consists of three open pits (Porcupine, Creek and Snowshoe), two waste rock dumps (Porcupine Creek and Clinton Creek) along the south side of Clinton Creek, and a tailings pile on the west side of Wolverine Creek (Figure 1-1).

From 1968 until depletion of economic reserves in 1978, the Cassiar Mining Corporation extracted approximately 12 million tonnes of ore from the open pits. Over 60 million tonnes of waste rock from the open pits was deposited in the Clinton Creek and Porcupine Creek valleys forming the Clinton Creek and Porcupine Creek Waste Rock Dumps. The ore was transported by aerial tramway to the mill located on a ridge along the west side of Wolverine Creek, which is a tributary of Clinton 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 (Wolverine Creek tailings piles).

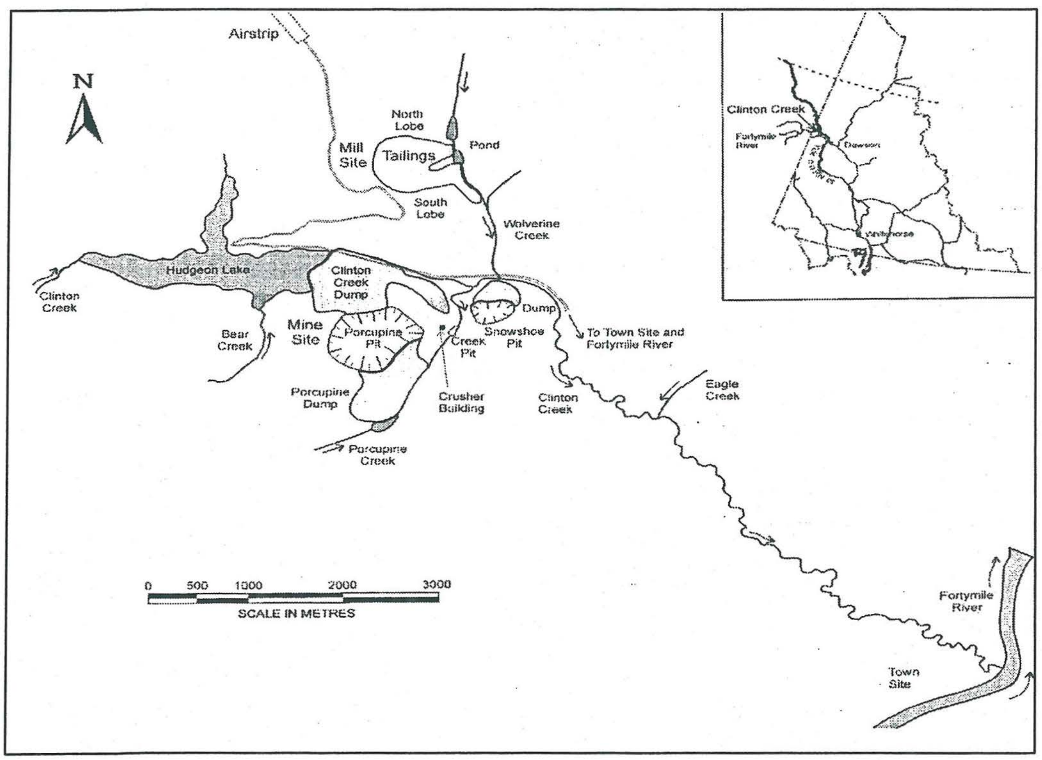

Figure 1-1: Former Clinton Creek Asbestos Mine Site

2.0 2004 Hazard Mitigation Work

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 General Contractor for the work was Hän Construction Ltd. of Dawson City, YT. The work was completed under a contract between the Government of Yukon – Energy, Mines and Resources (GY-EMR) and Hän Construction Ltd.

The hazards identified are summarized on Tables 1 and 2 and Drawings 01 and 02 of the in the Hazard Assessment Report. Tables 1 and 2 have been updated and re-issued in this report based on the hazard mitigation work completed in 2004 and are included in Appendix A.

2.1 Demolition Work

The demolition work was largely undertaken by a Sub-Contractor, Visco Demolition Contractors Ltd. of Edmonton, Alberta, with some assistance from the General Contractor. With the exception of concrete rubble, the demolition materials (e.g. steel, tin, machinery) were stockpiled near the proposed landfill site just north of the former crusher building at the location shown on Drawing 2-1. Photograph 2-1 shows the demolition material stockpile. Most of the demolition material has some degree of asbestos fibres adhered to the surfaces.

The demolition work completed is listed as follows along with the Feature ID number from the hazard assessment tables in Appendix A:

The demolition work undertaken is listed as follows:

- Demolish former Crusher Building (ID# 82) ,
- Demolish all remaining Tram Towers except Tower #3 (ID# 52, 54, 55, 56, 57, 58, 59, 60, 62, 82),
- Demolish Tram Terminus Building (ID# 48),
- Demolish two concrete buildings from the former office building at the Mill Site (ID #13, 12),
- Demolish and backfill three utilidor access structures at the Mill Site (ID #18, 23 – note: a third structure was discovered in 2004 – ID # 2004-01),
- Demolish and backfill both of the concrete conveyor tunnels at the Mill Site (ID # 22, 25, 26),
- Demolish the water storage and fuel storage tanks at the Mill Site (ID # 24, 28),
- Demolish the ANFO Storage Facility (ID#66).

A complete set of digital photographs of the demolition work is included on the attached Compact Disc.

Structures that were not demolished are the large, heavily reinforced concrete foundations at the former mill site and crusher building and Tram Tower #3 (Photographs 2-2 to 2-4). These structures were left in-place because the amount of reinforcing steel would make it very difficult to completely remove the foundation and they are considered to have a negligible to low hazard classification. Tram Tower #3 is a massive block of reinforced concrete located mid-way up the valley slope on the north side of Clinton Creek and is not readily accessible. The access ladder rungs were cut-off to prevent people from climbing the structure.

2.2 Other Work

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

The work completed is listed as follows along with the Feature ID number from the Hazard Assessment Report (UMA 2004):

- Re-grade five areas on the Clinton Creek Waste Rock Dump having visible concentrations of raw asbestos fibre and serpentinite rock (Drawing 2-1). These areas were covered over with argillite waste rock material,

  Note: The area directly west of the crusher building (ID #80) was re-graded to bury some asbestos tailings type material and flatten the side slopes.

- Re-grade the Mill Site area in and around the locations of the buildings to cover or mix in the surface layer of asbestos tailings dust into the native soils (i.e. silt) (Drawing 2-1),
- Bury the concrete rubble and voids left over from demolition of the concrete structures at the Mill Site (ID # 13, 14, 15, 18, 22, 23, 25, 26, 27, 45) Crusher Building (ID # 82) and ANFO Storage Facility (ID #66),
- Backfill pits in the former Service Building foundation slab (ID # 17, 44),
- Backfill the steel boiler plate utilidor shaft (ID #16),
- Remove wooden stair case leading down to the old Hudgeon Lake water intake point (ID #5),
- Move steel frame and wooden shelter to demolition material stockpile area (ID # 83, 84)
- Block two access roads on to the Clinton Creek Waste Rock Pile (Drawing 2-1),
- Block access road past the former Crusher Building (Drawing 2-1),
- Block access road down to the Creek and Snowshoe Pits (Drawing 2-1),
- Block entrance into Snowshoe Pit (Drawing 2-1),
- Block access road along the east side of Wolverine Creek (Drawing 2-1),

Digital photographs of the majority of this work are included on the attached Compact Disc.

2.3 Remaining Work

As indicated on the Hazard Summary Tables in Appendix A, the remaining work to mitigate the physical hazards at the site include:

- Landfill and/or salvage the demolition material stockpiled just north of the former Crusher Building site,
- Assess the options for the old mining equipment (ID # 81)
- Remove hydro poles and wire from Hudgeon lake (ID #5)
- Remove steel hopper from concrete foundation at the former crusher building,
- Demolish and backfill the wooden box culvert at the Mill Site (ID # 33)

At the time the demolition material stockpile is landfilled and/or salvaged, consideration should be given to gathering the miscellaneous debris metal laying around the former crusher building area and either landfilling or salvaging this material.

3.0 Monitoring Program

3.1 General

The monitoring program at Clinton Creek includes surveying movements on the Clinton Creek Waste Rock Dump (waste rock) and the Wolverine Creek Tailings Pile (tailings) and a profile survey of the Clinton Creek channel. Regular monitoring of the tailings was discontinued in 1984 and monitoring of the waste rock and Clinton Creek profile were discontinued in 1986. Monitoring of the waste rock and the creek profile was re-initiated in 1999 by Indian and Northern Affairs Canada (INAC) with a subsequent survey in 2001. In 2003, the monitoring program was assumed by the Government of Yukon – Energy, Mines and Resources (GY-EMR) and revised to include the tailings and augment the waste rock monitoring program. In July 2004, the waste rock monitors, tailings monitors and Clinton Creek channel profile were surveyed. The tailings monitors were surveyed again in September 2004.

All surveys before 2003 were completed using a Total Station survey referenced to the local mine grid co-ordinate system. Beginning in 2003, Global Positioning Survey (GPS) referenced to the UTM NAD 83 (Zone 7) co-ordinate system was used. A transformation routine was developed by Underhill Geomatics in Whitehorse to convert previous surveys completed in the former mine grid co-ordinate system to the UTM NAD 83 (Zone 7) co-ordinate system. The horizontal accuracy of the GPS survey is within 2 to 3 cm, which is acceptable given magnitude of movements expected and given the systematic error in positioning the survey rod at exactly the same location for each monitoring event. The main reasons for switching to a GPS survey include:

- more efficiency on a large site with significant topographical relief,
- more flexibility in confirming and establishing permanent benchmarks and establishing new monitoring points on the waste rock and tailings pile where direct lines of sight are difficult to achieve due to topographical relief,
- many of the prisms on the existing monitoring points were missing or not functional and could not be surveyed from a remote location (i.e. a rodman with a prism pole was required to go to most points).

The monitoring protocol and mine site benchmarks are provided in Appendix B (Table B-1 and Drawing B-1). Table B-1 also includes the conversion from the former mine grid co-ordinate system to UTM NAD 83 (Zone 7).

3.2 Clinton Creek Waste Rock Dump

Although no large displacements of the waste rock pile have been recorded since the monitoring program was re-initiated in 1999, continued monitoring is important to quantify continued creep movements that could impact channel stabilization works (gabion drop structures) constructed directly downstream of the Hudgeon lake outlet between 2002 and 2004. Stabilization of the waste rock may not be required provided that creep movements of the waste rock do not impact the gabion drop structures. If these creep movements impact the drop structures then stabilization of the waste rock or re-construction of the gabion drop structures may be necessary (UMA 2003).

The monitoring results from the 1999 and 2001 surveys are provided in two separate reports (UMA 2002 and UMA 2003) prepared for INAC. Due to the length of time between the 1986 and 1999 monitoring events only minimal data interpretation was possible, however the rate of movement did appear to be slowing with time. Post 2001 surveys indicate that since 1999, the annual horizontal movements range from 1 to 11 cm with an average rate of 7 cm. There were no signs to indicate strain rates were increasing, observations that would be expected if large movements of the waste rock were imminent. The observed creep movements may continue at similar rates for many years in particular if they result from channel erosion (i.e. toe erosion and down cutting) along the north edge of the waste rock located along Clinton Creek.

In 2003, the monitoring program was revised from seven monitoring points to forty-two (UMA 2004). The additional monitoring points consist 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 are located along the toe of the waste rock dump, which also forms the south bank of the creek.

The locations of the survey points are summarized on Drawing 3-1 and on Table B-2 in Appendix B. The waste rock movement monitors have been categorized according to location on the waste rock dump that is, the lower slope monitors are located below elevation 420 m, the mid-slope monitors are located between elevation 420 m and 450 m and the upper slope monitors are located above elevation 450 m. The Porcupine Pit slope monitor points are not included in these categories since they provide data on pit wall movements rather than waste rock movements.

A summary of the waste rock movement monitoring for the upper, mid and lower slope areas are provided on Tables B-3, B-4 and B-5 in Appendix B. The results from 1999, 2001, 2003 and 2004 show annual rates of horizontal waste rock movements from 1 to 13 cm with an average of 5 cm. The movement vectors shown on Drawing 3-1 suggest that the areas closest to Hudgeon lake are moving towards the lake while the rest of the pile is generally moving in a northerly direction towards Clinton Creek. While the average annual movement of the waste rock pile is small compared to previous (historical) observations, continued movements at this rate will eventually impact the integrity of the gabion drop structures. For example, at an average rate of 5 cm per year, about 0.5 m of horizontal displacement of the drop structures would occur over a 10 year period.

Since 2004, the monitoring program also includes measurement of the gabion drop structures to determine if the waste rock pile movements are impacting (i.e. squeezing) the drop structures. Each drop structure is measured at the two locations shown on Drawing B-2 in Appendix B. The measurements for Drop Structures 1, 2, 3 and 4 are provided in Table B-6 of Appendix B, which includes measurements from May 2005. The results from 2005 suggest that 1 to 12 cm of lateral movements may have occurred, which is comparable to the magnitude of the waste rock movements. Although the drop structures are not showing any signs of distress at this time, continued monitoring is required to assess long term impacts the waste rock movements may have on the drop structures.

The monitoring results for the Porcupine Pit slope monitors suggest that there is little movement of the pit walls at the location of the monitors (Table B-7 in Appendix B). The unstable areas of the open pit are quite obvious upon visual inspection. In general, the south west and south east corners of the pit are the most unstable and susceptible to large and sudden failures.

3.3 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. Drawing 3-2 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 is 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 on Drawing 3-2 suggests that a significant amount of erosion (i.e. 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 may be responsible for the majority of erosion seen between the 1986 and 1999 creek profiles. The surveys in 1999, 2001 and 2004 suggest that minimal erosion has occurred in recent years.

3.4 Tailings Pile

Based on the monitoring period from August 2003 to July 2004, the tailings pile is still moving but likely at rates less than originally thought. When the monitoring program was re-instated 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 of the tailings along Wolverine Creek. A series of alignment pins were also located in a straight lines across the toe of the north lobe (points NL-1 to NL-5) and south lobe (points SL-1 to SL-5) to provide a means to visually check for movements. The central observation point, NL – Base, is located on a bench on the south lobe which appears to be stable. The locations of the monitoring points are shown on Drawing 3-3. Tables B-8 to B-11 in Appendix B provide a tabular summary of the monitor points and measured movements.

The monitor points have been grouped according to their location on the slope, that is the upper, mid and lower slope areas (Drawing 3-3). 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.

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. As shown in Table 3-1, the horizontal movement rates calculated from the 2003 and 2004 monitoring data show that the movements are considerably less than previously measured and speculated on in previous reports (UMA 1999).

Table 3-1: Tailings Movement Rate Summary

SLOPE AREA	NORTH LOBE			SOUTH LOBE		
	1984	2003 to 2004		1984	2003 to 2004	
	(m / yr)	(m / yr)	% of 1984 Movement	(m / yr)	(m / yr)	% of 1984 Movement
Upper	0.4 to 9.0	0.01 to 0.10	< 3%	0.5	0.24	50%
Mid	1.6 to 24.5	0.01 to 0.63	< 2.5%	7	0.4 to 1.0	14%
Lower	20	0.08 to 0.17	1%	0.5 to 2.8	0.07 to 0.76	27%

3.4.1 South Lobe

The movement rates prior to 1984 and for the 1 year period between 2003 and 2004 are summarized in Table 3-1. The south lobe is the most active, particularly in the mid slope area which moved horizontally about 0.9 m between August 2003 and July 2004. Monitors 24D and 25B on the lower slope of the south lobe moved about 0.6 and 0.3 m, respectively, over the same time period possibly indicating that some mounding of the tailings at the valley bottom is taking place. The direction of the movements, as indicated by the vectors on Drawing 3-3, indicate the mid-slope area of the south lobe is generally moving east (i.e.

towards Wolverine Creek) with a slight northward component. The lower slope area appears to be moving north east and south east, possibly as a result of lateral spreading. The upper slope monitors of the south lobe (Monitors 1492 and 24) where large movements have not occurred to date are moving relatively slowly (i.e. less than 0.24 m per year).

3.4.2 North Lobe

Recent monitoring shows that the movements of the north lobe are small in comparison to the south lobe. The majority of the movements were measured along the south and east edges of the mid- slope area (i.e. all mid-slope monitors except 1085, 500-1 and 650-1) with less movement of the lower slope monitors. These mid-slope monitors moved about 20 cm, except 80-4 and 80-5 which moved 0.59 and 0.4 m, respectively. In general, less than 0.03 m of movement was seen in many of the remaining monitors which is about the accuracy of the survey method used.

3.4.3 Summary Of Movements

Although the movement rates appear to be significantly less than observed upto 1984, additional monitoring is necessary to confirm the movement rates observed between 2003 and 2004. The lower slope of the south lobe appears to be spreading to the north and south more than it is moving east across the valley. This behaviour is indicative of passive resistance (i.e. toe support) to downslope movement resulting from tailings mounding against the east valley slope.

Based on the recent movement rates measured and the height and length of tailings along Wolverine creek, the volume of tailings eroded annually is estimated to be in the order of 1,500 m^3 per year.

3.5 Monitoring Recommendations

The monitoring programs at the former Clinton Creek Asbestos Mine should be continued. Based on the observed rates of movement, the waste rock pile monitors and the Clinton Creek channel profile should be surveyed every second year. The next survey should be undertaken in the summer of 2006. The gabion drop structures should be measured at least once per year during site inspection visits to determine if the structures are being impacted by movements of the waste rock pile.

The tailings should be monitored annually for the next two years (i.e. 2005 and 2006) to confirm the annual movement rates and trends. The monitoring frequency can be reviewed following the 2006 monitoring event. Approximately five monitoring points should be added to the lower slope of the South Lobe to supplement the existing monitors in the zone where lateral spreading is suspected. The locations of these points will be provided in a separate letter following the spring 2005 site visit.

4.0 2004 Air Monitoring Program

4.1 Field Program

The 2004 Air Monitoring Program consisted of collecting air and soil samples across the mine site, characterizing the soil and vegetation at the monitoring sites and recording meteorological data.

The air monitoring program was undertaken in two stages, from July 13th to 26th and August 21st to September 2nd by Gil Robinson, P.Eng. of UMA Engineering Ltd. while on-site for the Clinton Creek Channel Stabilization Work - Stage III (UMA 2005). No samples were collected between July 26th and August 21st because the creek stabilization repairs were on-hold and the demolition activities were underway, which may temporarily have resulted in elevated levels of airborne asbestos. Air monitoring was conducted by Hän Construction Ltd. during the demolition work. These results are not included in this report as they don't relate to the ambient conditions before or after the demolition work.

Sixty air samples (50 area and 10 personal samples) were collected at the locations shown on Drawing 4-1. The locations are summarized on Table C-1 in Appendix C. The area samples represent ambient air conditions and the personal samples represent 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 bull dozer. 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.

The air samples were collected using seven Gil-Air personal air sampling pumps (Photograph 4-1). The flow rate of the pumps were set to 2.5 litres per minute that is, 1,200 litres over an 8 hour sampling period. The average sampling periods for the area and personal samples were about 530 (8.8 hours) and 160 (2.7 hours) minutes, respectively. A new 25mm diameter PCM sampling cassette was used for each sample. From each box of sampling cassettes, one unused PCM sample cassette was taken as a blank sample and analyzed to determine background levels of fibres in the cassettes.

At each sampling location, site conditions including vegetative cover and soil moisture were noted and are provided on Table C-2 in Appendix C. Representative photographs and soil samples were taken in the main areas of the mine site (Drawing 4-1) where air sampling was conducted. A summary of the soil samples is provided on Table C-3 in Appendix C. Photographs of the site conditions and soil samples are included on the Compact Disc.

The weather conditions for each sampling event were recorded using a weather station setup at the Mill Site at the location shown on Drawing 4-1. A summary of the meteorological data is included in Appendix D and a complete set of the data is provided on the attached Compact Disc.

4.2 Laboratory Testing

All air samples, including the two blank samples (AIR-0 & 39) were analyzed for fibre concentration using the phase contrast, light microscopy (PCM) technique. The PCM method 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. Samples AIR-0, 13, 14, and 15 were tested on-site by Mike Hannusch of UMA Engineering. The remainder of the samples were submitted for testing to EnviroTest Laboratory (ETL). The PCM test results are included in Appendix C. A summary of the results can be found on Table C-4 in Appendix C. Digital copies of the test results are also included on the attached compact disc.

Fourteen air samples (AIR-20, 23, 26, 29, 32 to 38, 40, 48 and 55) were also analyzed using the Transmission Electron Micoscopy (TEM) technique. The TEM method allows for differentiation between asbestos and non-asbestos fibres of all diameters. The selected samples were forwarded by ETL to Lab/Cor, Inc. in Seattle, Washington. An American lab was used because there are no companies in Canada that do commercial testing using the TEM technique. The samples selected for TEM analysis include all the personal samples, except AIR-13, and a set of area samples (AIR-33 to 38) collected on the same day (August 24, 2004) at various areas across the mine site. The results of the TEM testing are provided in Appendix C along with a summary on Table C-4.

All twelve soil samples (G-01 to G-12) collected from the various mine areas were submitted to ETL to determine the asbestos content and to determine the type of asbestos fibres present. The samples were analyzed using the Polarized Light Microscopy (PLM) method. The testing results are attached in Appendix C along with a summary on Table C-3.

4.3 Site Conditions

As discussed in the Hazard Assessment Report (UMA 2004), the mine closure work undertaken after the mine was closed appeared to be focussed on building demolition. Since that time very little work has been completed at the site. As discussed in Section 2 of this report, a hazard mitigation work program was undertaken in the summer of 2004 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 (Drawing 2-1),
- re-grading some localized areas on the Clinton Creek Waste Rock Dump having a significant amount of serpentinite rock (i.e. low grade ore) (Photograph 4-2 and Drawing 2-1),
- covering raw asbestos fibres just north of the Porcupine Pit (Drawing 2-1),
- burying most of the asbestos ore located west of the former Crusher Building (Photograph 4-3 and Drawing 2-1) and
- re-grading much of the ground surface at the former Mill Site that was covered with tailngs (Photograph 4-4 and Drawing 2-1).

4.3.1 Site Conditions At Air Sampling Points

Drawing 4-1 shows the locations of the mine areas discussed below and the corresponding air sampling locations. In general, the air samples collected in these areas were taken under dry conditions however, some samples were also collected within a few days of some precipitation events for comparative purposes.

Mine Area 1) Former Air Strip

The air strip is located along a ridge about 800 m north of the former Mill Site (Area 2) and is accessible by road from the Mill Site. As shown in Photograph 4-5, the air strip has a sparse covering of trees and beyond the limits of the air strip the terrain is well covered with trees. The soils at the air strip consist of a brown silt with traces of sand and gravel and no visible concentrations of asbestos. The PLM test result for soil sample G-06 indicates that there are no asbestos fibres. A photograph of the soil sample collected at this site is included on the attached Compact Disc. Three air samples were collected in this area, samples AIR 11, 29 and 38. Air 29 is a personal sample taken in Areas 1, 2 and 3.

Mine Area 2) Former Mill Site

The Mill Site is located directly west of the tailings pile on the top of a mountain ridge and is accessible by road from the upper ford crossing at the outlet from Hudgeon Lake. Access across the ford crossing is intermittent depending on the flow depth in the outlet channel from the lake. As shown in Photograph 4-6 the Mill Site has limited vegetation and is covered with a layer of tailings. Four soil samples were collected in Area 2 (G-05, G-10, G-11 AND G-12) at the locations shown on Drawing 4-1. The PLM test results suggest the percentage of asbestos fibres range from 1 to 50 percent. Photographs of the soil samples are included on the attached Compact Disc. Much of the Mill Site was re-graded in August following the demolition work to cover the tailings with natural materials, similar to those found at the air strip. The re-graded conditions are illustrated in Photograph 4-7. Thirteen air samples were collected in this area, samples AIR-4, 6, 10, 22, 27, 29, 46, 47, 53, 54, 56, 58 and 59. Air 29 is a personal sample taken in Areas 1, 3 and 4.

Mine Area 3) Wolverine Creek Tailings Pile

The tailings pile is located on the west side of the Wolverine Creek valley and extends from the mountain ridge (i.e. Mill Site) down to the valley bottom. The upper slope area of the tailings pile is accessible by road from the Mill Site. The lower slope (i.e. toe area) of the tailings are accessible by foot or ATV along Wolverine Creek. As shown in Photograph 4-8, the tailings pile has virtually no vegetative cover. The surface of the tailings has been weathered to form a soft crust that is easily disturbed by human activities. The tailings consist of crushed serpentinite rock and fine asbestos fibres rejected during the milling process. Based on a bulk sample of the tailings submitted for gradation analysis (UMA 2004) it is comprised of about 68% sand and gravel, 27 % silt and 5% clay sized particles i.e. 32% of the particles were less than 50μm in diameter. The PLM test results from sample G-04 indicate the tailings have 10 to 25% asbestos fibres. A photograph of the soil sample is included on the attached Compact Disc. Fifteen air samples were collected in this area, samples AIR 3, 5, 9, 21, 23, 24, 25, 28, 29, 32, 37, 45, 52, 57 and 59. Air 23, 29 and 32 are personal samples. Sample Air 32 was taken in Areas 3 and 4.

Mine Area 4) Wolverine Creek

Wolverine creek is a tributary stream to Clinton Creek. It is accessible off the main mine road by foot or ATV. The valley floor is covered with tailings which were mainly deposited after a breach of the tailings pile occurred in the mid-1970's (UMA 2003). Since that time, additional tailings have likely been eroded from the tailings pile and deposited in Area 4. Vegetative cover generally consists of trees along the creek banks and similar to the tailings pile, there is little vegetative cover where the tailings deposits are thick. In the summer of 2002, 2003 and 2004, a construction camp was located in Area 4 on the west side of Wolverine Creek at the main access road. The site conditions are illustrated on Photograph 4-9. Directly north of the main mine road, some serpentinite rock containing asbestos fibres is exposed along the east side of the valley. Two soil samples (G-01 and G-02) were collected at the locations shown on Drawing 4-1. The PLM test results indicate there is up to 25 percent asbestos fibres in the soil. Photographs of the soil samples collected at this site are included on the attached Compact Disc. Six air samples were collected in Area 4, samples AIR 17, 18, 30, 31, 32 and 35. Air 32 is a personal sample taken in Areas 3 and 4.

Mine Area 5) Porcupine Pit

Porcupine Pit is located between the Clinton Creek and Porcupine Pit waste rock dumps. The area is accessible by foot or ATV only because the two roads off the main mine road onto the Clinton Creek Waste Rock Dump have been blocked. As shown on Photograph 4-10, there is little to no vegetation in this area. The soils in and around the open pit mainly consist of argillite, serpentinite and raw asbestos fibres. At the north end of the pit near sampling location AIR-34, the ground was covered with raw asbestos fibres, as shown in Photograph 4-11. The fibres were not loose but matted together. The majority of the raw asbestos fibres were covered over with argillite on July 24, 2004. Air samples AIR 02 and 34 were collected before and after the areas was regraded, respectively.

Mine Area 6) Snow Shoe and Creek Pits

The Snow Shoe and Creek Pits are located north east of the Porcupine Pit and are accessible by foot or ATV only because the two roads off the main mine road onto the Clinton Creek Waste Rock Dump have been blocked. As shown in Photograph 4-12 there is little to no vegetation in this area. The soils in and around the open pits mainly consist of argillite, serpentinite and raw asbestos fibres. The floors of the open pits are covered with raw asbestos fibres as shown in Photograph 4-11. The fibres are not loose but matted together. The PLM test results for soil sample G-07 collected in this area suggests that the surface soils contain upto 50 percent asbestos fibres. A photograph of the soil sample is included on the attached Compact Disc. Four air samples were collected in this area, samples AIR 12, 33, 42 and 49.

Mine Area 7) Crusher Building Area

The Crusher Building area is located on a rock outcrop between the two open pit areas. This area is also accessible by foot or ATV only because the two roads off the main mine road onto the Clinton Creek Waste Rock Dump have been blocked. As shown on Photograph 4-13, there is little to no vegetation in this area. The Crusher Building was demolished in August 2004 and the surrounding area was regraded to cover the asbestos fibres (both raw fibres and tailings sized fibres) leftover from operation of the mine. The area still has raw asbestos fibres at ground surface intermixed with rock and fine grained soils. The PLM test results for sil sample G-08 collected in this area suggest the surface soils contain upto 75 percent asbestos. A photograph of the soil sample is included on the attached Compact Disc. Eight air samples were collected in this area, samples AIR 1, 13, 14, 15, 16, 43, 50 and 61. Air 13 is a personal sample worn by a bulldozer operator during regrading work undertaken in this area.

Mine Area 8) Clinton Creek Waste Rock Dump

The Clinton Creek Waste Rock Dump is located between the Porcupine Pit and Clinton Creek. Even though the two access roads onto the main area of the dump have been blocked it is readily accessible by foot and ATV off of the main mine access road, which runs along the north edge of the waste rock pile. The material forming the dump is mainly argillite bedrock removed from the Porcupine Pit. A few discrete areas of the dump contain serpentinite rock with asbestos fibres (low grade ore). These areas were covered over with argillite in the summer of 2004, as illustrated in Photograph 4-2. About two to three weeks after the regrading work was completed, a crust formed on the argillite due to weathering. There is very little vegetation on the waste rock pile although trees have sprouted along the edges of the old haul roads located on the dump, as shown on Photograph 4-14. The PLM test results for soil samples G-03 and G-09 collected in Area 8 suggest the surface soils contain upto 25 percent asbestos fibres. Photographs of the soil samples are included on the attached Compact Disc. Eight air samples were collected in this area, samples AIR 7, 8, 19, 26, 36, 44, 51 and 60. Air 26 is a personal sample.

Mine Area 9) Porcupine Creek Waste Rock Dump

The Porcupine Creek Waste Rock Dump is directly southeast of the Porcupine Pit and is only accessible by foot and ATV. The material forming the dump is mainly argillite bedrock removed from the Porcupine Pit but also contains areas of serpentinite rock with low grade asbestos ore. There is very little if any vegetation on the waste rock pile. No air samples were collected in this area.

Mine Area 10) Former ANFO Storage Site

The former ANFO Storage Site is located on a ridge south of the Porcupine Pit and is not readily accessible. Access to this area is by foot or ATV only. The general area is well vegetated with trees, grass and clover. The surface soils in this area are mainly silt. No air samples were collected in this area.

4.3.2 Meteorological Conditions

A HOBO Weather Station with a data logger was setup at the Former Mill Site at the location shown on Drawing 4-1 and Photograph 4-15. The station was equipped with the following sensors: rain gauge, temperature, dew point temperature, relative humidity, wind speed and wind direction. Data was recorded at five minute intervals from July 19 until September 17, 2004. Microsoft Excel spreadsheets with the raw data are provided on the attached Compact Disc. The daily statistics for the data collected, including minimum, average and maximum values, are provided in Appendix D along with a separate summary of the daily statistics for each day that air sampling was conducted.

In general, the weather conditions in the summer of 2004 at the Former Clinton Creek Mine Site were considered to be very dry as supported by the high incidence of forest fires in the northern part of the Yukon and across the border in Alaska. Although the weather station was not setup until mid-July, it is believed that very little, if any, precipitation had fallen since early June when a rainstorm passed over the mine site during a site visit. This is generally supported by the low water flows measured at the Clinton Creek Hydrometric Station (Figure D-1 in Appendix D). While the weather station was operating, a total of 82 mm of rainfall was measured of which, 72 mm of rain fell between July 21 and August 1 followed by 5 mm on August 27, 4 mm on September 2 and 3 and 1 mm on September 14, 15.

4.4 Air Monitoring Program Results

All of the air samples collected in 2004 were analyzed by Phase Contrast Microscopy (PCM) and selected samples were analyzed by Transmission Electron Microscopy (TEM). PCM analysis is used primarily for estimating asbestos concentrations in air to show compliance with regulatory limits. PCM is a contrast-enhancing optical technique that can be used to produce high-contrast images of transparent specimens. The phase contrast technique employs an optical mechanism to translate minute variations in phase into corresponding changes in amplitude, which can be visualized as differences in image contrast (http://www.microscopyu.com/articles/phasecontrast/phasehome.html; accessed April 11, 2005). The PCM method 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. The estimated limit of detection for the PCM method is 7 fibres/mm^2 filter area (which equates to approximately 5.5 fibres in 100 fields of view). A "field of view" is the area within the boundaries of the graticule, which is observed under the microscope for fibre counting purposes (UMA 2004 - Appendix D). The result is reported as less than the calculated detection limit where less than 5.5 fibres are counted in 100 fields, which is based on the number of fibres as well as on the volume of air sampled.

In TEM, a beam of highly focused electrons are directed toward a thinned sample (<200nm). These highly energetic incident electrons interact with atoms in the sample producing a characteristic radiation and particles providing information for materials characterization. According to the Centre for Microanalysis of Materials, because the electron beam goes through the sample, transmission microscopy reveals the interior of the specimen (http://cmm.mrl.uiuc.edu/techniques/tem.htm; accessed April 12, 2005). It gives structure: the size, shape, and the distribution of the phases that make up the material. TEM provides for the identification of both asbestos and non-asbestos as well as thin fibres in air (i.e. less than about 0.25 micrometres in diameter).

The testing results of the sixty air samples (50 area and 10 personal samples) collected between July 13 to September 2, 2004 are provided on Table C-4 in Appendix C. The results of 45 of the 50 area samples analyzed by PCM were less than the calculated analytical detection limits (<0.01 to 0.001 fibres/ml based on air volume sampled). The 5 area sample results shown in Table 4-1 below were above the detection limits:

Table 4-1: PCM Testing Results for Area Samples

Sample #	Area (see Drawing 4-1)	Conditions	Result (Fibres/ml)
14	7) Crusher Bldg.	Dry	0.001
17	4) Wolverine Creek	Moist to wet	0.01
36	8) Waste Rock Dump	Dry	0.004
37	3) Wolverine Creek Tailings	Dry	0.003
38	1) Former Airstrip	Dry	0.004

Meteorological conditions provided in Appendix D indicate that there was a rain event on July 22, 2004 and one event on August 1,2004. The July 22nd rain event would have affected air sample number 17 which was collected on July 24, 2004 while the other four samples were collected during dry periods. While it is reasonable to assume that wet conditions would likely result in lower airborne asbestos concentrations than dry conditions, the result for sample number 17 was the highest fibre concentration (0.01 fibre/ml) for the area monitoring program. Other rain events were recorded in late July, early August and September, but did not appear to have any significant influence on the other 45 area airborne asbestos results reported as less than the calculated analytical limit of detection for asbestos in air for both dry and wet conditions. The daily average values for wind speeds during the sampling periods for the 5 positive area samples ranged from 2.0 to 8.6 kph with daily average wind gusts ranging from 4.3 to 15.1 kph respectively. For the entire 2004 monitoring season, average daily wind speeds ranged from 2.0 to 8.6 kph and average daily wind gusts ranged from 4.0 to 15.1 kph. Maximum daily values recorded during the 2004 sampling events ranged from 6.0 to 25.4 kph for wind and 10.7 to 42.8 kph for wind gusts. Both rain events and wind did not appear to influence the PCM test results on the area samples as the highest level of airborne asbestos was recorded for both wet conditions and relatively calm conditions (i.e. average daily wind speed 3.6 kph and average daily wind gust 6.8 kph).

It should be noted that the pump time for sample number 17, and therefore the volume of air sampled, was considerably less that the other four area samples which may have influenced the result. The calculated analytical limit of detection for PCM ranges from <0.001 to <0.01 fibres/ml and there is a wide-range of acceptable variability. For example, if a sample yields a count of 24 fibres, the mean inter-laboratory count will fall within the ranges of 227% above and 52% below that value 90% of the time (NIOSH Manual of Analytical Methods, Fourth Edition, 8/15/94). The 2004 asbestos in air PCM results for the area monitoring indicate that ambient airborne asbestos was at or near detection limits for all area locations monitored.

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, as discussed above, do 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. The highest personal sample result was collected during the September 2, 2004 sampling event where dry to wet conditions were recorded and wind conditions were relatively calm (daily average values, wind speed 3.2 kph and wind gusts 6.1 kph). 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 limit of detection.

Table C-4 also provides the TEM results for the selected areas and personal monitoring events. A total of 14 TEM results (6 area and 8 personal) were obtained. The reported laboratory analytical sensitivity ranged from 0.000 to 0.004 fibres/ml and all of the results where within the 95% confidence interval. The airborne asbestos results for the 6 area monitoring stations (samples Air-33, 34, 35, 36, 37 and 38) 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. Although it is reasonable to assume PCM results would be comparable to TEM total fibre concentrations because PCM does not differentiate between asbestos and non-asbestos fibres, the TEM total fibre concentrations for the six area samples tested were higher than the respective PCM results. This may be due to the low values near the limits of detection, the variability of the PCM analytical protocol and ability for TEM to measure thin diameter fibres. The asbestos fibre concentrations determined on these six samples by TEM are relatively low and also comparable to the corresponding PCM test results. The six area samples submitted for TEM testing were collected on August 24, 2004. The meteorological conditions were dry with the strongest wind and wind gusts recorded during the 2004 monitoring season.

The asbestos fibre concentrations for the eight personal samples (samples Air-20, 23, 26, 29, 32, 40, 48 and 55) submitted for TEM testing ranged from 0.008 to 0.118 fibres/ml. As discussed above, it is reasonable to assume that the TEM airborne asbestos fibre concentrations would be less than the PCM values. However, two of the eight personal samples (samples Air 20 and 40) had TEM asbestos fibre results that were higher than the corresponding PCM results. This may be due to variability of the PCM analytical protocol, the higher accuracy of the TEM analytical protocol and the quantification of smaller diameter fibres by TEM. The total fibre concentrations from TEM testing on all of the personal samples, except Air -48, were close to or higher than the corresponding PCM values. The TEM asbestos fibre concentrations for the personal samples are 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.

PCM results for seven personal samples collected during August 2003 that range from <0.01 to 0.22 fibres/ml are also provided on Table C-4. Of these samples, the sample with the high value of 0.22 fibres/ml was collected at the Mill site during reconnaissance activities. In 2004, the remaining buildings at the Mill site (i.e. Area 2) were demolished and backfilled with local borrow material (i.e. silt and sand) and the ground surface at the Mill site was largely re-worked with a bulldozer to cover asbestos fibres. A detailed description of the demolition work is provided in Section 2.0. The personal samples collected in 2004 were collected during physical activities conducted at multiple locations across the mine site. The laboratory results for both PCM and TEM (asbestos fibres only) ranged from 0.03 to 0.118 fibres/ml (samples Air-20 and 40, respectively). This indicates that the remedial activities undertaken in 2004 have reduced airborne asbestos fibre concentrations.

5.0 Screening Level Risk Assessment For Airborne Asbestos

5.1 Introduction

A number of environmental assessments have been conducted since 1974 at the former Clinton Creek asbestos mine site. Most of these studies were geophysical assessments, with a focus on the movements and stability of the tailings piles or characterization of the waste rock pile. A few studies focused on levels of asbestos in water and the potential impacts to fish habitat. These studies are summarized in an environmental review and screening environmental risk assessment report conducted by Royal Roads University in 1999 (RRU, 1999) for Indian and Northern Affairs Canada (INAC). The RRU report assessed aquatic habitat, terrestrial habitat, and the geochemical stability of waste materials, based on limited sampling.

The 1999 RRU report stated that airborne asbestos in the vicinity of the former mine site is probably of minimum consequence for human health or other animals, but recommended some minimum measurements of airborne concentrations during worst-case, extreme dry, windy periods (e.g., during the late summer after an extended period without rainfall). The actual extent of human exposures at Clinton Creek is expected to be much less than would occur in an occupational setting (for example, during the operation of the asbestos mine), where the daily and long-term exposure duration of inhalation exposures would be much greater. The RRU study concluded that human health related risks which may merit further examination include cancer risk due to the inhalation of friable chrysotile asbestos fibres in the terrestrial environment based on occasional site visits.

In 2003, SENES Consultants Limited provided a screening environmental risk assessment of the former Clinton Creek Mine site, as part of a series of Screening Level Risk Assessments (SLRAs) of eleven mine sites and thirteen former military sites in northern Canada on behalf of INAC (SENES, 2003). The SENES 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 from the SLRA 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 an assumption, however, that humans reside at the site year round, and could be potentially exposed to the contaminants three months out of a twelve month year.

In 2003, UMA prepared a hazard assessment report (UMA 2004) on the former Clinton Creek Mine site for the Government of Yukon. The objectives of the work were to identify and classify human health and safety hazards, and provide prioritized recommendations for potential corrective measures. The air sampling program recommended in this report was established in 2004 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 (Drawing 4-1). The asbestos air sampling program was also used to confirm that workers at the site involved in the stabilization of the Clinton Creek channel (UMA 2005) were not exposed to unacceptable levels of airborne asbestos fibres.

The results of the air sampling program conducted in the summer of 2004, indicated that exposure to asbestos fibres is likely to occur during any activity in areas of the mine site where the ground surface is covered with asbestos. The airborne asbestos fibre levels measured were below the Yukon 8-hour permissible exposure limit of 0.5 fibres/ml. The widespread existence of loose asbestos fibres on the ground, abandoned equipment and structures at Clinton Creek asbestos mine are potential sources for airborne contamination. As part of an overall mine closure plan, actual asbestos inhalation risks from occasional site visits needed to be better evaluated. The Hazard Assessment Report (UMA 2004) provided a suggested approach for the additional assessment of human health risks and recommendations on further air monitoring.

It is appropriate with respect to the previous screening environmental risk assessment (RRU 1999), SLRA (SENES 2003), Hazard Assessment Report (UMA 2004) and the recently completed hazard mitigation work, that a revised SLRA specific to human health exposure risk to airborne asbestos be undertaken. It should be noted that a screening assessment is characterized by simple, qualitative, and/or comparative methods, and relies heavily on literature information and previously collected data (CCME 1996). The following provides a SLRA for human exposure to airborne asbestos at the former Clinton Asbestos Mine site.

This SLRA is focussed entirely on potential human health risks associated with inhalation of airborne chrysotile asbestos, which was the type of asbestos fibre mined at Clinton Creek. It is based on new air monitoring data that was not available when the previous SLRA (SENES 2003) was completed. In addition, potential human site use is evaluated in more detail, and on a site-specific basis.

5.2 Site Characterization

As shown on Drawing 5-1, the former Clinton Creek Asbestos Mine is located about 100 km northwest of Dawson City in the Yukon Territory, 9 km upstream of the confluence of Clinton Creek and the Forty Mile River. Access to the former mine site is by gravel road from the Top of the World Highway (TWH) and is maintained by the Government of Yukon down to Forty Mile River bridge during the summer months from about May to the end of September. The mine access road from the Forty Mile River bridge to the mine site is not maintained. As shown on Drawing 4-1, the mine consists of three open pits (Porcupine, Creek and Snow Shoe), two waste rock dumps (Porcupine Creek and Clinton Creek), and a tailings pile on the west side of Wolverine Creek. During the operational period of the mine between 1968 and 1978, asbestos fibres were widely spread across the mill site and surrounding areas in various concentrations as a result of mining operations. Based on the condition of the mine site at the time of the hazard assessment work in 2003 (UMA 2004), it is obvious that no efforts were undertaken to clean-up the deposits of un-milled and milled asbestos fibre after the mine was closed. Asbestos fibres, including large aggregations, were visually obvious in the soils at various locations around the mine site in particular at the Mill Site, Tailings Pile, Tramway, Crusher Building and the Open Pits. Some localized deposits were also observed on the Waste Rock Piles.

Development of the three open pits, of which the Porcupine Pit is the largest, resulted in the deposition of argillite waste rock and some serpentinite rock containing low grade ore on the waste rock dumps. The presence of unprocessed ore, including asbestos fibres, on the floor of the Snowshoe and Creek Pits and near the entrance to the Porcupine Pit presents a potential human health hazard. The waste rock predominantly consists of argillite and the volume of the waste rock piles has been estimated to be 60 million tonnes (Stepanek and McAlpine 1992). Asbestos fibres are occasionally found amongst the waste rock. Asbestos fibres in soil samples (Table C-3 in Appendix C) collected in 2004 at the air monitoring locations ranged from 25 to 50% asbestos fibres in Snowshoe Pit (Soil Sample G-07) and 10 to 25% asbestos fibres in the waste rock pile (Soil Samples G-03 and G-09). The locations of the soil samples are shown on Drawing 4-1. Hazard mitigation activities undertaken in 2004 included blocking both access roads onto the waste rock pile, the road into Snow Shoe Pit and the road access to the Porcupine Creek Waste Rock Dump past the former crusher building location. Raw asbestos fibres on the ground surface just north of the Porcupine Pit were covered with argillite waste rock material. The majority of the areas on the Clinton Creek Waste Rock Dump where serpentinite rock containing low grade ore existed were coved over with argillite waste rock material. This work is described in Section 2.0.

The crusher building was located on a rock outcrop between the three open pits. With the exception of the primary and secondary crushers and the screen deck, most of the main components of the crusher building were not removed during the mine decommissioning. Asbestos fibres on the roof of the building, inside the building, in the ore buckets and in the surrounding area were identified in the Hazard Assessment program. Asbestos content of soil samples collected in 2004 west of the former Crusher building on the re-graded area ranged from 50 to 75% asbestos fibres (Soil Sample G-08). Asbestos fibres were also identified along the former tram line including the tram terminus building located on the Mill Site (Drawing 2-1). The tram terminus building was clad with asbestos fibre board. In 2004, the crusher building was demolished, the general area was re-graded and access roads to this area of the mine site were blocked. The Tram towers and terminus structure were removed, foundations demolished and backfilled, and asbestos fibres covered.

The mill produced approximately one million tonnes of long fibre chrysotile asbestos and almost 12 million tonnes of tailings (Stepanek and McAlpine, 1992), which were deposited onto the Wolverine Creek valley slope. The tailings consist of crushed serpentinite rock and fine asbestos fibres rejected during the milling process. Based on a bulk sample of the tailings submitted for gradation analysis (UMA 2004) it is comprised of about 68% sand and gravel, 27 % silt and 5% clay sized particles i.e. 32% of the particles were less than 50μm in diameter. Based on the PLM test results, asbestos fibres in soil samples collected in 2004 ranged from 10 to 25% asbestos fibres at the top of the tailings pile (Sample G-04), the north west corner of the mill site (Sample G-11) and the center of the Mill site (Sample G-05). Sample G-10 near the south end of the Mill Site had 25 to 50% asbestos fibres. The tailings were deposited at the top of the valley slope and in 1974 a failure of the south lobe blocked Wolverine Creek (UMA 2003). This blockage was breached and the eroded tailings were deposited downstream of the tailings pile. Deposits of asbestos tailings can be found along the Wolverine Creek channel to the confluence with Clinton Creek, a distance of approximately 800 m. The tailings deposits, which are up to 2 m thick, are exposed along the flanks of the channel and the flood plain to the valley slopes. Asbestos fibres were also observed hanging from trees within the channel during the 2003 Hazard Assessment Program. Asbestos content of the soil sample collected (Sample G-01) from the bed of Wolverine creek, just upstream from the mine access road, ranged from 10 to 25% asbestos fibres. NOTE: the bulk samples collected in 2003 by SENES indicate there is about 60 to 70 percent fibres on the tailings, mill site areas. Appendix D, Table 2.2 of the Hazard Assessment Report (UMA 2004).

In 2004, the remaining buildings at the Mill site were demolished and backfilled with local borrow material (i.e. silt and sand). The ground surface at the Mill site was largely re-worked with a bulldozer to cover asbestos fibres. A detailed description of the demolition work is provided in Section 2.0.

The mine access road from the Forty Mile River bridge to Wolverine Creek has been improved due to site activities undertaken between 2002 and 2004. Previously, the edges of the road were overgrown with trees that would prevent the passage of large vehicles. New trees have started to grow and will eventually reduce site access to larger vehicles. Access across the lower Clinton Creek ford crossing just west of Wolverine Creek deteriorates with each spring freshet event and is impassable during moderate to high flows. Access across the upper Clinton Creek ford crossing at Hudgeon Lake outlet is mainly dependent on water levels in the lake. Access to the Mill site is depending on the ford crossings and with vegetation re-growth along the mine access road from the Forty Mile River bridge, will become limited. Access by automobile up Wolverine Creek has been blocked just north of the mine access road.

The 2004 hazard mitigation work has resulted in significant changes to the former Clinton Creek Asbestos Mine site characteristics that would likely have some impact on the assessment of potential risk posed by human exposure to airborne asbestos. However, even with the recent hazard mitigation work, there remain large areas of the former mine site where potential human exposure to airborne asbestos may occur. These areas include the Mill site, Wolverine Creek Tailings Pile, Wolverine Creek, the open pits

(Porcupine, Snowshoe and Creek), the former Crusher building area and to a lesser extent, the two waste rock dumps.

During the 2004 hazard mitigation work and air monitoring program, site conditions at the air monitoring locations were recorded and are provided in Section 4.3. A meteorological station was established at the Mill site to record the meteorological conditions during the hazard mitigation work and air monitoring program. The meteorological data is briefly discussed in Section 4.3.2 and provided in Appendix D. During the air monitoring program between July and September 2004, there were only a few rain events that occurred during the middle and end of July, and early August and September. The amount of precipitation during these events ranged from 0.4 to 24.0 mm. The total monthly rainfall was 59.8 mm, 17.4 mm, and 5.0 mm for July, August and September, respectively. With the exception of air monitoring events on July 24th and 26th, August 30th and September 2nd, the site conditions were very dry.

Overall, the areas of concern at Clinton Creek include:

- Open pits, from which serpentine parent materials were extracted;
- Waste rock dump areas;
- The Mill site where asbestos fibres were physically separated from the host rock;
- "Tailings" or mill waste, generated as discards from the crushing and physical separation of longer, higher quality fibres from shorter fibres and other materials;
- Wolverine Creek valley which has deposits of tailings; and
- Roadways or other access areas affected by the storage, handling and transport of mined, pre-processed and final processed asbestos.

5.3 Hazard Assessment

Asbestos is a generic term for a group of six naturally occurring fibrous minerals: amosite, chrysotile, crocidolite, and the fibrous varieties of tremolite, actinolite and anthophyllite. The most common mineral type is 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. It is also listed in the U.S. Environmental Protection Agency's (USEPA) Toxic Release Inventory as an Occupational Safety and Health Administration (OSHA) carcinogen.

Most health information on asbestos exposure has been derived from studies of workers who have been exposed to asbestos in the course of their occupation. Inhalation is the principal route of exposure to asbestos. The Agency for Toxic Substances and Disease Registry (ATSDR) states that significant exposure to any type of asbestos will increase the risk of lung cancer, especially mesothelioma, and non-malignant lung and pleural disorders, including asbestosis, pleural plaques, pleural thickening, and pleural effusions. This conclusion is based on observations of those diseases in groups of workers with cumulative exposures ranging from about 5 to 1,200 fibre-year/ml. Such exposures would result from 40 years of occupational exposure to air concentrations of 0.125 to 30 fibres/ml. When asbestos fibres are inhaled, most fibres are expelled, but some can become lodged in the lungs and remain there throughout life. People are likely to experience asbestos-related disorders when they have been exposed for longer periods of time, and/or are exposed more often. Various factors determine how exposure to asbestos affects an individual. These include exposure concentration, exposure duration, exposure frequency, size, shape and chemical makeup of asbestos fibres and individual risk factors, such as a person's history of tobacco use and other pre-existing lung disease.

Currently there are no available soil quality guidelines in Canada for asbestos, however, a number of limits have been established for occupational exposure to airborne asbestos. The current OSHA permissible exposure limit (PEL) for asbestos is 0.2 fibres/ml of air as a time-weighted average (TWA) concentration over an 8-hour work shift with an action level of 0.1 fibre/ml as an hourly TWA. The Yukon

PEL for asbestos is 0.5 fibres/ml as a TWA concentration. The U.S. National Institute for Occupational Health and Safety (NIOSH) has a recommended exposure limit (REL) of 0.1 fibre/ml as a TWA concentration for up to an 8-hour work shift, 40-hour work week. The issue of acceptable exposure thresholds is addressed further in Section 5.6: Effects Assessment.

5.4 Receptor Characterization

Human "receptors" refer to people who live and work in the area, and can potentially be exposed to the chemicals of potential concern associated with the former Clinton Creek Asbestos Mine. For this SLRA, the chemical of potential concern is asbestos and the primary exposure pathway is inhalation. Clinton Creek represents an atypical situation where there are currently a very limited number of permanent human receptors and a limited number of transient human receptors. As shown on Drawing 5-1, the former Clinton Creek town site is located approximately 8 kilometres south east of the mine site. Two adults, male and female have built a log cabin in the former Clinton Creek town site which they currently occupy for part of the summer. In the future, they may reside year round. Two other adults, male and female live year round in the area on the Forty Mile River, about 30 kilometres upstream of the former Clinton Creek town site. There are a few part-time residents in the general area. A trapper/commercial fisherman resides part-time in a cabin on Mickey Creek, on the south side of the Forty Mile River approximately 1.6 kilometres south of the Forty Mile River bridge. One of his trap lines is located near the former airstrip. A miner lives in a gravel pit part-time during the summer on the Clinton Creek road south of the Forty Mile River. In addition, the Yukon Heritage Branch has a project to restore the former Forty Mile town site located approximately 9 kilometres northeast of the mine site (i.e. at the confluence of the Yukon and Forty Mile rivers). Approximately six construction workers stay at the former Forty Mile town site over the summer. Another male and female operate a commercial fishing operation during the summer out of the former Forty Mile town site. There is also significant activity during the summer months at the landing above the former Forty Mile town site as it is a termination point for canoe float trips from Dawson City as well as providing supplies to those who are residing in the area.

Currently there are two year-round residents, twelve part-time residents based on available information. Two of the part-time residents may eventually become year-round residents and there are a number of transient visitors to the area during the summer and late fall for fishing and hunting activities. It is also reasonable to assume that there will 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, the potential for exposures 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;
- times when surface soils and asbestos-containing waste deposits are dry and when surface wind speeds are higher than average.

The instantaneous concentrations of asbestos fibres in the various areas of concern are expected to be very strongly influenced by the temporally variable meteorological conditions. There is limited, partially complete meteorological data for Clinton Creek for the years 1966 to 1978, when the mine was in operation. Wind speed data are not available for the site. As shown in Figure 5-1, the monthly average air temperatures for the region are below freezing between early October and early April, and the potential for mobilization of chrysotile asbestos fibres in the air during this period is expected to be very low due to the fact that the ground would be frozen, and based on snow cover. Precipitation events are relatively common in the region from May through September. There is no long term data on the average number of days with precipitation (trace amounts or greater) during these months; however, UMA site observations suggest that days with trace levels of precipitation are common. In light of this, potential for asbestos fibre introductions to ground air masses from contaminated soils would be temporally limited based on meteorological conditions alone.

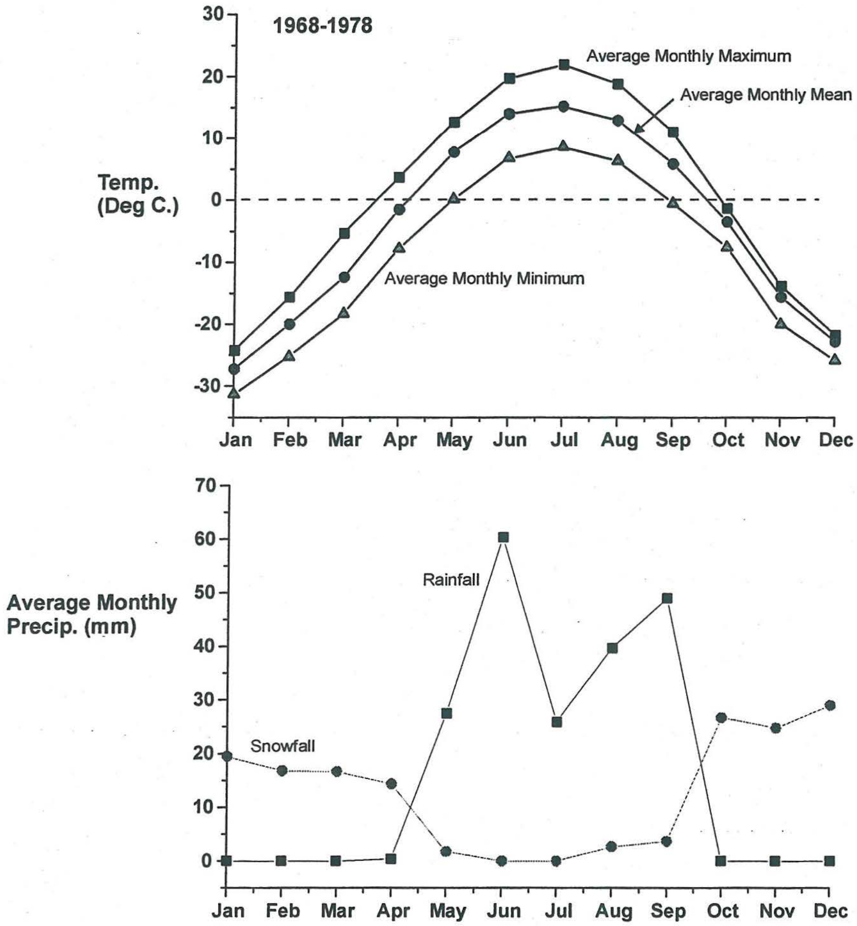

Figure 5-1: Climatic Conditions at Clinton Creek, Yukon based on data from 1968 to 1978.

Chrysotile asbestos, and its serpentinitic 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. While such crusts may be subsequently disturbed by freeze-thaw cycles and other events, the main point is that the threshold wind velocities of mobilization of asbestos fibres into air from the contaminated soils are expected to be much higher than would be predicted based on the size and mass of individual asbestos filaments. As discussed in Section 3, the tailings pile is still creeping downslope and this action may result in the exposure of some localized areas of un-weathered asbestos tailings which are more susceptible to disturbance by wind.

The potential for elevated airborne concentrations of chrysotile asbestos could increase if humans were involved in activities that disturb soils directly. For the Clinton Creek site, an obvious example of this would be 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. Although it is not certain if this work is necessary it has been discussed in other reports (UMA 2003).

In light of the above, the receptor of concern at the site is 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 would be expected to result in lower risks.

5.5 Exposure Assessment

The basic structure of asbestos is (SiO_4). The chemical formulae for the asbestos types are amosite ($[Mg, Fe]_7Si_8O_{22}[OH]_2)n$; chrysotile ($Mg_3Si_3O_5[OH]_4$); crocidolite ($[NaFe_{32}+Fe_{23}+Si_8O_{22}[OH]_2)n$; tremolite ($[Ca_2Mg_5Si_8O_{22}\{OH]_2)n$; actinolite ($Ca_2(Mg,Fe)_5Si_8O_{22}[OH]_2)n$; and anthophyllite ($[Mg,Fe)_7Si_8O_{22}[OH]_2)n$. All asbestos fibres are solids, insoluble in water and organic solvents, and are non-flammable. Chrysotile is soluble in acid. Asbestos is a naturally occurring fibrous mineral that is not mobile in soil. 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, however, ingestion and dermal contact are other exposure pathways.

The Hazard Assessment Report (UMA 2004) provided an approach to Human Health Risk Assessment that recommended as a minimum better information on airborne asbestos concentrations at the site under different meteorological conditions and based on different levels of disturbance including:

- Ambient conditions;
- Walking across the mine site;
- Camping at the mine site; and
- Vehicular traffic, including use of All Terrain Vehicles (ATVs).

The 2004 Air Monitoring Program is discussed in Section 4.0 and an Air Monitoring Summary is provided in Appendix C. A total of 60 air samples were collected between July and September 2004 at the former Clinton Creek Mine site. Only 15 of the 60 samples exceeded the analytical PCM detection limits ranging from <0.001 to <0.01 fibres/ml based on air volume sampled, and of these, 10 were collected as personal samples measured during site activities. Table C-3 provides a summary of the 50 ambient air sampling and the 10 personal/activity samples. The following tables, Tables 5-1 and 5-2, provide a summary of the 15 positive airborne asbestos results determined using the PCM test method based on ambient and personal/activity sampling scenarios:

Table 5-1: Ambient Airborne Asbestos (PCM Test Method)

Sample #	Date	Area (see Drawing 4-1)	Conditions	Result (Fibres/ml)
14	20-Jul-04	7) Crusher Bldg.	Dry	0.001
17	24-Jul-04	4) Wolverine Creek	Moist to Wet	0.01
36	24-Aug-04	8) Waste Rock Dump	Dry	0.004
37	24-Aug-04	3) Wolverine Creek Tailings	Dry	0.003
38	24-Aug-04	1) Former Airstrip	Dry	0.004

Table 5-2: Personal/Activity Airborne Asbestos (PCM Test Method)

Sample #	Date	Activity	Area (see Drawing 4-1)	Conditions	Result (fibres/ml)
13	20-Jul-04	Bulldozer operator	7) Crusher Bldg.	Dry	0.02
20	24-Jul and 24-Aug-04	Driving/Walking	Multiple Areas	Moist to wet	0.03
23	26-Jul-04	Walking	3) Wolverine Creek Tailings	Dry to moist	0.04
26	21-Aug-04	ATV	8) Waste Rock Dump	Dry	0.03
29	22-Aug-04	ATV	1, 2) Airstrip, Mill Site	Dry	0.03
32	23-Aug-04	ATV	3, 4) Wolverine Creek Tailings, Wolverine Creek	Dry	0.06
40	24-Aug-04	Driving/Walking	Multiple Areas	Dry	0.054
41	26-Aug-04	Driving/Walking	Multiple Areas	Dry	0.041
48	30-Aug-04	Driving/Walking	Multiple Areas	Moist	0.05
55	02-Sep-04	Driving/Walking	Multiple Areas	Dry to Moist	0.074

The meteorological data is provided in Appendix D. Conditions at the air sampling locations were reported to be mostly dry during sampling activities, with the exception of the sampling periods of July 24th, and 26th; August 30th and September 2nd. These correspond to the air sampling conducted following rain events recorded by the meteorological station:

- July 21 & 22, 2004 35.6 mm of rainfall
- August 27, 2004 5.2 mm of rainfall
- September 2, 2004 1 mm of rainfall

The 2004 air monitoring program assessed to some degree airborne fibre concentrations under a range of weather conditions. However, it should be noted that between October to May, the former Clinton Creek Mine site will have varying levels of snow cover thereby reducing potential exposures to asbestos fibres.

Based on the above, the maximum expected airborne fibre concentration experienced by a person at the site who is involved in activities that disturb surface soils is 0.12 fibres/ml air, at a height above ground suitable for inhalation. A lower bounds estimate is around 0.02 asbestos fibres/ml air. In 2003, a concentration of 0.22 fibres/ml was determined by PCM at the former Mill site. Considerable remedial activities have occurred at this site as has been previously discussed and the 2004 results, determined by both PCM and TEM, are more reflective of current conditions and provide a greater level of confidence.

The following table, Table 5-3, provides a summary of the TEM results of selected area and personal/activity sampling conducted during 2004.

Table 5-3 Summary of TEM Test Results for Selected Area and Personal/Activity Samples

Sample #	Date	Activity	Area (see Drawing 4-1)	Condition	Total (fibres/ml)	Asbestos (fibres/ml	Non-Asbestos (fibres/ml)
20	24-Jul and 24-Aug-04	Driving/ Walking	Multiple Areas	Moist to wet	0.123	0.063	0.060
23	26-Jul-04	Walking	4) Wolverine Creek	Dry to moist	0.038	0.010	0.028
26	21-Aug-04	ATV	8) Waste Rock Dump	Dry	0.083	0.015	0.068
29	22-Aug-04	ATV	1, 2, 3) Airstrip, Mill Site, Tailings	Dry	0.062	0.014	0.048
32	23-Aug-04	ATV	3,4) Wolverine Tailings, Wolverine Creek	Dry	0.102	0.027	0.075
33	24-Aug-04	Area Sample	6) Snow Shoe Pit	Dry	0.001	<0.001	0.001
34	24-Aug-04	Area Sample	5) Porcupine Pit	Dry	0.007	0.002	0.005
35	24-Aug-04	Area Sample	4) Wolverine Creek Valley	Dry	0.006	0.002	0.004
36	24-Aug-04	Area Sample	8) Waste Rock Pile	Dry	0.008	0.002	0.006
37	24-Aug-04	Area Sample	3) Tailings Pile	Dry	0.007	0.001	0.006
38	24-Aug-04	Area Sample	1) Air strip	Dry	0.005	0.000	0.005
40	24-Aug-04	Driving Walking	Multiple	Dry	0.241	0.118	0.123
48	30-Aug-04	Driving Walking	Multiple	Moist	0.012	0.008	0.004
55	02-Sep-04	Driving Walking	Multiple	Dry to moist	0.107	0.033	0.074

5.6 Effects Assessment

The USEPA, as part of their Integrated Risk Information System (IRIS), has developed a chronic *inhalation unit risk value* for asbestos (http://www.epa.gov/iris/subst/0371.htm; last accessed 30 March 2005) with a value of 0.23 incremental cancers per (f/ml). This was based on use of a low dose extrapolation method, which in turn was based on an "additive risk of lung cancer and mesothelioma, using relative risk model for lung cancer and absolute risk model for mesothelioma".

This, in turn would translate to acceptable air concentrations for a variety of incremental lifetime cancer risk levels, as follows:

Table 5-4 Risk Levels and Air Concentrations

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

It should be noted, however, that these values assume a long-term chronic exposure in epidemiological studies of exposed worker populations.

Acute studies have been undertaken especially to examine fibre clearance rates from pulmonary tissue (http://www1.umn.edu/eoh/hazards/hazardssite/asbestos/asbestostoxdynamics.html; accessed March 30, 2005), which in turn is correlated with carcinogenic activity. The different carcinogenic potential of different asbestos and silicaceous materials is due in large part to differences in the persistence of the fibres in deep lung tissue. For chrysotile asbestos, typical clearance half-lives are in the range of 4 years, 6 years and 8 years for fibres that are <5 µm, 5-10 µm or >10 µm in length, respectively.

Asbestosis has not been known to occur in the absence of extended exposure periods (i.e. ten years or more) (Bridgman, 2001); so the major focus of the risk characterization for Clinton Creek is potential for the development of mesenthelioma and other forms of lung cancer.

To account for cumulative exposure via inhalation of asbestiform 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 air over a ten year period would be exposed to 1 fibre per ml year, or 1 fibre-year/ml (Bridgman, 2001). USEPA (IRIS) provides a summary of the epidemiological studies in light of estimated cumulative exposures (Table 5-5).

Table 5-5: Collated Dose-Response Data for Asbestos Inhalation and Carcinogenicity (adapted from USEPA, IRS: http://www.epa.gov/iris/subst/0371.htm; accessed 30 March 2005)

Human Data Occupational Group	Fibre Type	Reported Average Exposure (fibre-yr/mL)	% Increase in Cancer per fibre-yr/mL	Reference
Lung Cancer:				
Textile Products	Predominantly Chrysotile	44	2.8	Dement et al., 1983b
Textile Products	Chrysotile	31	2.5	McDonald et al., 1983a
Textile Products	Chrysotile	200	1.1	Peto, 1980
Textile Products	Chrysotile	51	1.4	McDonald et al., 1983b
Friction Products	Chrysotile	32	0.058	Berry and Newhouse, 1983
Friction Products	Chrysotile	31	0.010	McDonald et al., 1984
Insulation Products	Amosite	67	4.3	Seidman, 1984
Insulation Workers	Mixed (Chrysotile, al., 1979 Crocidolite and Amosite)	300	0.75	Selikoff et
Asbestos Products		374	0.49	Henderson and Enterline, 1979
Cement Products		89	0.53	Weill et al., 1979
		112	6.7	Finkelstein, 1983
Mesothelioma:				
Insulation workers	Mixed	375	1.5E-6	Selikoff et al., 1979; Peto et al., 1982
Insulation Products	Amosite	400	1.0E-6	Seidman et al., 1979
Textile Products Manufacturer	Chrysotile	67	3.2E-6	Peto, 1980; Peto et al., 1982
Cement Products	Mixed	108	1.2E-5	Finkelstein, 1983

See url reference for citations

The USEPA and UK have used the same epidemiological data to develop their risk guidance for chrysotile asbestos inhalation. A cohort of asbestos textile workers in Rochdale exhibited an excess risk of six extra deaths at age 80 years for every 1,000 individuals exposed. (Bridgman, 2001). The greatest risk was experienced by individuals who began work at or around age 20 and worked for 35 years, at an average airborne chrysotile fibre concentration (<5 μm length) of 0.25 fibres/ml. From this epidemiological study, Doll and Peto (1985) developed a linear, non-threshold model (which implies that any chrysotile exposure, no matter how small or brief, will result in some increase in risk) described by the following equation:

$$\textbf{Relative risk} = \textbf{O/E} = 1 + \textbf{b} \times \textbf{cumulative exposure} \qquad [1]$$

Where:

O is the number of cases observed,

E is the number of cases expected in the absence of chrysotile exposure,

b is a constant (0.0006; Hughes, 1985), and

cumulative exposure is in fibres - year/ml.

Bridgman (2001) provides an example of the use of this equation to assess the risks of mesenthelioma and lung cancer based on short term exposures of a UK population following a fire with asbestos-containing fallout.

As mentioned in Section 5.3, some regulatory limits for occupational asbestos fibres are as follows:

- OSHA permissible exposure limit (PEL): 0.2 fibres/ml of air as a time-weighted average (TWA) concentration over an 8-hour work shift with an action level of 0.1 fibre/ml as an hourly TWA.

- Yukon PEL for asbestos is 0.5 fibres/ml as a TWA concentration.

- The U.S. National Institute for Occupational Health and Safety (NIOSH) has a recommended exposure limit (REL) of 0.1 fibre/ml as a TWA concentration for up to an 8-hour work shift, 40-hour work week.

- For measurement of asbestos fibre concentrations in the outside atmosphere, to which the general public may be exposed continuously, the Ontario Ministry of the Environment (MOE) suggested a "guideline" of 0.04 fibre/mL (fibres longer than 5 μm) measured by TEM in the 1980s.

5.7 Risk Characterization

Given the intermittent exposures expected at the site, equation [1] of Section 5.6 was used to calculate incremental lifetime cancer and mesenthelioma risks based on the expected site use at the Clinton Creek former asbestos mine.

The measured concentrations of chrysotile fibres in air (fibres/ml), using personal air monitoring data, were converted to measures based on cumulative exposures (fibres per ml year).

Assumptions:

- Plausible range of maximum airborne chrysotile concentrations at breathing height: 0.02 to 0.118 fibres/ml;

- Maximum lifetime exposures based on time spent on site = 20 years x 3 months/12 months x 8 h/24 h;

Based on this, the expected maximum cumulative exposure (equation 1) is estimated to be in the range of 0.033 to 0.20 fibres-year/ ml. This can be compared with the estimated exposure values from epidemiological studies summarized in Table 5-5.

From the estimated cumulative exposure, the maximum estimated relative risks are calculated as follows:

$$\textbf{Observed/Expected} = 1 + 0.0006 \times 0.20 \textbf{ fibres per ml year} \qquad [2]$$

$$= 1.00012$$

Using the range of expected maximum cumulative exposure, the observed expected cancer incidence is estimated to be in the range of 1.00002 to 1.00012. **This equates to an incremental lifetime cancer risk (ILCR) in the range of 2×10^{-5} to 1.2×10^{-4}.**

Note, however, 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, is estimated to have a maximum cumulative exposure (equation 1) of 0.00018 to 0.0011 fibres per ml year, and an ILCR (equation 2) in the range of **1.1×10^{-7} to 6.6×10^{-7}**. Table 5-6 provides a summary of the incremental lifetime cancer risk based on the above assumed airborne asbestos concentrations, exposure durations and cumulative exposures.

Health Canada considers cancer risks to be essentially negligible (*de minimus*) when the estimated total ILCR is less than 1×10^{-5}. Figure 5-4 provides 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.

Senes (2003) in their SLRA of Clinton Creek, assumed an asbestos fibre concentration in air in the range of 0.01 fibres/ml (undisturbed areas) to 0.2 fibres/ml (disturbed area). The major difference between the SLRA in this report and the SLRA completed by SENES (SENES 2003) is that SENES further assumed an adult or toddler as on site all year round, and exposed to asbestos for 3 months of the year for their entire lifespan. This would result in an assumed cumulative exposure of 3.5 fibres-year/ml.

Based on the assumed site use, Senes estimated a cumulative chrysotile asbestos fibre intake on 4,400 fibres/kg body weight per day. This, along with a USEPA derived asbestos cancer slope factor of 1.03×10^{-6} $(\text{fibre/kg-d})^{-1}$ resulted in the calculation of an ILCR for adults of 4.5×10^{-3}. If the fraction of time exposed, however, is assumed to be less than 10 years in a persons lifespan, and for 8 hours or less in a 24 hour day, then the estimated ILCR would be 2.1×10^{-4}. Also, if the maximum airborne concentration is assumed to be 0.1 instead of 0.2 fibres/ml, this would further halve the estimate, rendering it similar to the worst-case estimate provided herein. Note also that the USEPA cancer slope factor used is highly conservative relative to slope factor estimates developed by some other regulatory agencies, both in the United States and elsewhere.

Table 5-6: Incremental Lifetime Cancer Risk Summary

Assumed Airborne Asbestos Concentration (fibres/ml)	Assumed Exposure Duration	Cumulative Exposure (fibres-yr/ml)[D]	Assumed Value of Constant 'b' in Eq'n [1]	Relative Risk[E] (observed/ expected)	Incremental Lifetime Cancer Risk[F]
0.02[A]	8 hours/d x 3 months/yr x 20 years	0.033	0.0006[C]	1.000020	2.0×10^{-5}
0.12[B]		0.20		1.00012	1.2×10^{-4}
0.02[A]	8 hours/d x 10 d/yr x 1 yr	0.00018	0.0006[C]	1.00000011	1.1×10^{-7}
0.12[B]		0.0011		1.00000066	6.6×10^{-7}
0.02[A]	8 hours/d x 3 months/yr x 20 years	0.033	0.01[C]	1.00033	3.3×10^{-4}
0.12[B]		0.20		1.0019	1.9×10^{-3}
0.02[A]	8 hours/d x 10 d/yr x 1 yr	0.00018	0.01[C]	1.0000018	1.8×10^{-6}
0.12[B]		0.0011		1.000011	1.1×10^{-5}

Notes:

A) Average measured airborne chrysotile asbestos concentration (TEM results) for 2004 (n = 14:Table 5-3).

B) Maximum measured airborne chrysotile asbestos concentration (TEM results) for 2004 (n = 14:Table 5-3).

C) See text (Section 5.8: Uncertainty in Assessment) for a discussion regarding the pros and cons of using the two different constants in concert with the Doll and Peto (1985) model. A constant of '0.01' is considered to produce a hyper-conservative estimate of lung cancer and mesenthelioma risks.

D) *Cumulative Exposure* – Maximum lifetime exposure based on the time spent on the former Clinton Creek mine site.

E) *Relative Risk* – The number of cancer cases observed/the number of cancer cases expected in the absence of chrysotile exposure.

F) *Incremental Lifetime Cancer Risk* – The increase in cancer risk due to the exposure of airborne Chrysotile asbestos a the former Clinton Creek mine site over a lifetime.

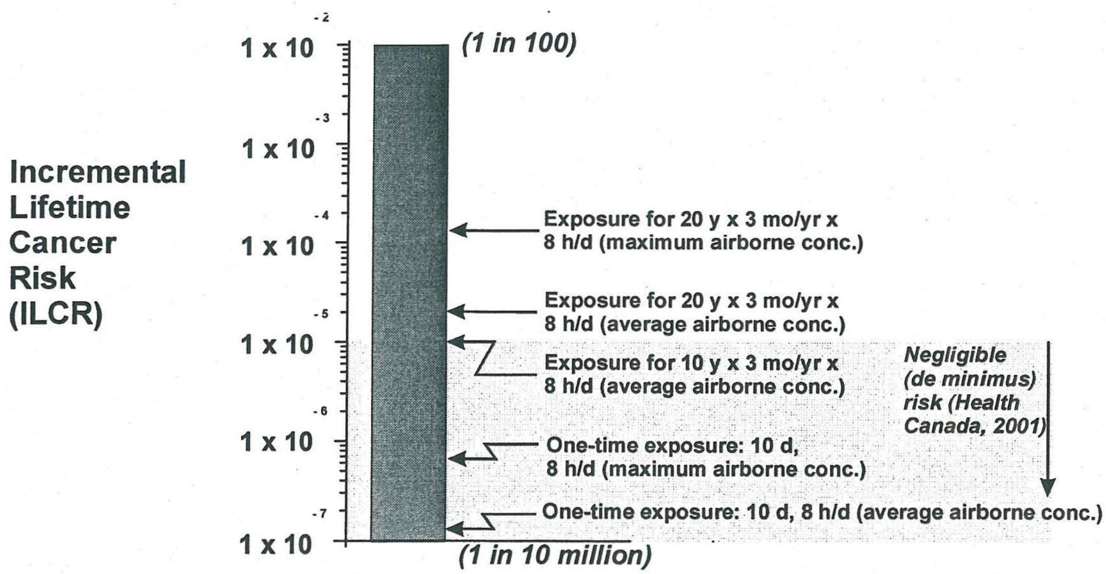

Figure 5-4: Summary of best upper-bound estimates of incremental lifetime cancer risks from airborne chrysotile asbestos at the former Clinton Creek asbestos mine, based on 2004 site conditions.

5.8 Uncertainty In Assessment

There remains considerable uncertainty about whether short term inhalation exposures to chrysotile asbestos can result in adverse health effects, and the extent to which information from long-term chronic, occupational exposures is useful for the types of incidental outdoor exposures evaluated here. Several regulatory agencies rely on the same epidemiological studies, as well as the Doll and Peto (1985) model for deriving risk guidance; however, it should be noted that there is controversy over the value of the constant 'b' (equation 1). According to Bridgman (2001),

> "In several mixed fibre cohorts and one chrysotile textile cohort a constant of around 0.01 has been found, and used to predict risk in the UK and USA. However, Hughes argues that for a population exposed to non-textile chrysotile, then available data suggest a constant of 0.0006 is more appropriate. Reasons for the differences may be the more pathogenic fibre dimensions in textile manufacture, inadequate adjustment for crocidolite exposure in Doll and Peto's (1985) model, and/or the use of carcinogenic and fibrogenic mineral oil sprays in the textile industry."

Use of a value of 0.01 rather than 0.0006 for the constant 'b' in Equation 1 would result in a further inflation of ILCR estimates by a factor of 17-fold, slightly more than one order of magnitude.

Since none of the epidemiological studies have been conducted at or near abandoned asbestos mines, there remains a possibility that the fibre lengths and particle types encountered may be very different between the studied occupational exposures and the Clinton Creek site. In particular, the waste rock and open pit areas of the Clinton Creek site predominantly contain un-milled fibres, the characteristics of 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.

The use of a single upper estimate of airborne fibre concentrations, based on the maximum measured concentration, is undoubtedly conservative in that it represents 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 obviously have a very large influence on estimates of cumulative exposures via inhalation. The assumed site use was based on our best knowledge of the site in light of current conditions. Regardless of the absolute risks, greater human use of or transit through the site will result in greater cumulative exposures.

In general, assuming that the Doll and Peto (1985) model with a constant of 0.0006 ('b') accurately describes mesenthelioma and cancer risks from chrysotile asbestos fibre inhalation at the former mine site, it is concluded that incremental lifetime cancer risks to individual humans who visit or temporarily reside at the site fall in the range of $<1 \times 10^{-7}$ to around 1.2×10^{-4}. The highest calculated risk is related to a full time resident on the mine site property, which is not presently occurring but 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.

5.9 Recommendations

Regardless of actual estimated magnitude of risk, it is often prudent to consider risk management activities that further reduce risks. It is anticipated that the hazards mitigation work undertaken in 2004 will further reduce exposures by (i) further limiting human access to former mine site areas; (ii) reducing the aerial extent of surface soils with high asbestos fibre concentration, and (ii) in the case of the mill site area especially, promoting future re-vegetation, which would further limit the extent of mobilization of chrysotile asbestos fibres from soil to air.

Potentially exposed individuals can also voluntary reduce their own magnitude of exposures if they have a better awareness of the site conditions and areas of concern. Especially with regard to the tailings deposit, local education/information programs as well as effective use of signage would encourage people to understand the risks and reduce their exposure potential.

The risk of exposure to airborne asbestos should be reassessed if the nature of human activity (i.e. site use) or condition of the site changes from the present day site use and conditions for which this risk assessment report is based upon. Reassessment of the risk of exposure to airborne asbestos fibres would require additional air quality monitoring and a rigorous comparison of the new monitoring results, site activity and conditions to the existing air monitoring data, site use and conditions.

Respectfully submitted,

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