Clinton Creek Mine Risk Review 2009

FINAL

Prepared for

Government of Yukon

Prepared by

SRK Consulting
Engineers and Scientists

Project Reference Number
SRK 1CY001.037

February 2010

Clinton Creek Mine

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Government of Yukon

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SRK Project Number 1CY001.037

February 2010

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1 Introduction

The Government of Yukon contracted SRK Consulting (Canada) Inc. (SRK) to facilitate a Risk Review of the Clinton Creek Mine. A Failure Mode, Effects and Criticality Analysis (FMECA) approach was used for this review. It consisted of a facilitated workshop with participation by Yukon Government, Federal Government and Tr'ondëk Hwëch'in personnel, several technical consultants who have a history with the site plus representatives of SRK. Following the workshop five failure modes were further evaluated to better quantify their likelihoods of occurrence and consequences. This report provides a summary of the risk review and the outcomes.

2 Purpose

The overall objective of the Clinton Creek Mine risk review is to provide further input to inform decision making on a closure plan or long-term maintenance at the site. A further objective is to assess whether the current risks are significant enough to warrant further remediation and if potential closure options will effectively reduce existing risks.

3 Workshop Participants

A full day workshop was held in the SRK offices in Vancouver, BC on September 3, 2009 to perform the FMECA. The following individuals participated in the workshop:

Yukon Government: Rachel Pugh

Federal Government: Brett Hartshorne (INAC Yukon Region)
Karen Ballantyne (INAC Yukon Region)
Andrew Liddiard (INAC HQ)

Tr'ondëk Hwëch'in: Micah Olesh, Lands and Resources Officer
Bill Kendrick, Lands and Resources Officer

HFM Consulting: Bud MacAlpine
Milos Stepanek

Brodie Consulting Ltd: John Brodie

AECOM Canada Ltd: Ken Skaftfeld
Gil Robinson
Rolf Aslund

SRK representatives: Daryl Hockley and Dirk van Zyl (workshop facilitator).

4 FMECA Process

In order to prepare the participants for the workshop a risk review PowerPoint presentation was distributed to all participants before to the workshop, refer to Appendix A. This presentation provided project objectives, scope, context and a brief review of the FMECA process.

In an FMECA the likelihood of occurrence of a specific failure mode is combined with the likelihood and severity of a consequence to express the risk. Figures 1 and 2 provide guidance for the likelihood and severity descriptors. Figure 3 is the risk matrix. These are consistent with the INAC risk review procedures.

Likelihood	Descriptor 2	Frequency Descriptor	Probability of Occurrence over Twenty Years	Probability of Occurrence in Any One Year
Almost Certain	Happens often	High frequency (more than once every 5 years)	98%	17.8%
Likely	Could easily happen	Event does occur, has a history, once every 15 years	75%	6.7%
Possible	Could happen and has happened elsewhere	Occurs once every 40 years	40%	2.5%
Unlikely	Hasn't happened yet but could	Occurs once every 200 years	10%	0.5%
Very Unlikely	Conceivable, but only in extreme circumstances	Occurs once every 1000 years	2%	0.1%

Figure 1: Likelihood Descriptors

Consequence Categories	**Very Low**	**Minor**	**Moderate**	**Major**	**Critical**
Environmental Impact	No impact.	Minor localized or short-term impacts.	Significant impact on valued ecosystem component.	Significant impact on valued ecosystem component and medium-term impairment of ecosystem function.	Serious long-term impairment of ecosystem function.
		UKHM: Ice plug release at Onek 400 adit	*UKHM: Tailings dam breach*	*Mt. Nansen: Failure of Main Dam leads to release of contaminated water & tailings into Victoria Creek*	
Special Considerations	Some disturbance but no impact to traditional land use.	Minor or perceived impact to traditional land use.	Some mitigatable impact to traditional land use.	Significant temporary impact to traditional land use.	Significant permanent impact on traditional land use.
		UKHM: Ongoing release of zinc into wetland areas			*Mt. Nansen: Tailings dam breach*
Legal Obligations	No non-compliance but lack of conformance with departmental policy requirement. Informal advice from a regulatory agency. No land claim or other agreement.	Technical/Administrative non-compliance with permit, approval or regulatory requirement. Warning letter issued. Land claim or other agreement requires the Crown to satisfy administrative obligations (e.g. notification).	Breach of regulations, permits, or approvals (e.g. 1 day violation of discharge limits). Order or direction issued. Land claim or other agreement requires the Crown to respond, but no time frame is specified.	Substantive breach of regulations, permits or approvals (e.g. multi-day violation of discharge limits). Prosecution. Land claim or other agreement requires the Crown to exercise its obligations within a specified time frame (i.e. 2-5 years)	Major breach of regulation – wilful violation. Court order issued. Land claim or other agreement requires the Crown to exercise its obligations within a specified short time frame (i.e. 1-2 years)
			Mt. Nansen: Hydrocarbon from historical spills seeps into receiving water	*UKHM: Tailings dam breach*	
Consequence Costs	< $100,000	$100,000 - $500,000	$ 500,000 - $2.5 Million	$2.5-$10 Million	>$10 Million
		Mt. Nansen: Erosion leads to loss of spillway		*Mt. Nansen: fire in mill leads to loss of power and treatment*	*UKHM: Tailings dam breach leading to tailings release*

Consequence Categories	Very Low	Minor	Moderate	Major	Critical
Community/ Media/Reputation	Local concerns, but no local complaints or adverse press coverage.	Public concern restricted to local complaints or local adverse press coverage.	Heightened concern by local community, criticism by NGOs or adverse local /regional media attention.	Significant adverse national public, NGO or media attention.	Serious public outcry/demonstrations or adverse International NGO attention or media coverage.
				UKHM: Tailings dam breach	
Human Health and Safety	Low-level short-term subjective symptoms. No measurable physical effect. No medical treatment.	Objective but reversible disability/impairment and /or medical treatment injuries requiring hospitalization.	Moderate irreversible disability or impairment to one or more people.	Single fatality and /or severe irreversible disability or impairment to one or more people.	Multiple fatalities.
			UKHM: Public access to boneyards leads to injury	*UKHM: Snow machine accident on waste rock leads to fatality*	*UKHM: Vehicle accident on poorly maintained road leads to multiple fatalities*

Figure 2: Consequence-Severity Descriptors

Likelihood	Consequence Severity				
	Low	Minor	Moderate	Major	Critical
Almost Certain	Moderate	Moderately High	High	Very High	Very High
Likely	Moderate	Moderate	Moderately High	High	Very High
Possible	Low	Moderate	Moderately High	High	High
Unlikely	Low	Low	Moderate	Moderately High	Moderately High
Very Unlikely	Low	Low	Low	Moderate	Moderately High

Figure 3: Risk Matrix

The workshop focused on identifying, describing and developing a risk ranking for specific failure modes associated with the waste dump and tailings areas. The experience of the participants and their collective familiarity with the various aspects of the Clinton Creek Mine were essential in developing the risk characterizations.

As an introduction to the meeting Dirk van Zyl provided a summary of the present conditions, a copy of this presentation is included in Appendix B. This was followed by a short presentation by Rachel Pugh to provide the context for the Risk Review Workshop, a copy of this presentation is included in Appendix C.

Physical boundaries for the risk review included the mine waste rock piles, the open pits and the tailings areas. The risk review focused on present site conditions and how they could change as a result of the identified failure modes.

The rest of the morning and part of the afternoon was devoted to listing, describing and discussing failure modes, effects, likelihoods and consequences. The results of these discussions are presented in Table 1.

The last part of the day was used to perform a “Criticality” evaluation. This is typically done for manmade mechanical and electrical systems by assigning values to the descriptors of effect likelihood and consequences and also including a value for the likelihood of detecting a failure mode prior to its occurrence. The values obtained for each of these three factors are then multiplied to obtain the criticality value. It is difficult to reliably estimate the likelihood of detecting a failure prior to its occurrence for failure modes involving natural materials and phenomena. Instead of following this approach for the Clinton Creek Mine FMECA five failure modes that resulted in one or more “high” risk ratings were selected as the critical failure modes.

5 Results

For the first two failure modes in Table 1 all the consequences were evaluated, this was done to allow participants to become familiar with the FMECA process. For most of the failure modes only a few consequences, and in some cases only one consequence, were evaluated. The selection of the consequences for a specific failure mode depended on the failure mode and its effects as well as the relative risks of other failure modes. For example, if the effect likelihood is unlikely to very unlikely then the risk will at most be moderately high for a critical consequence severity. For lower consequence severities the risk will be lower. This logic was followed for each failure mode identified during the workshop.

For three failure modes (Clinton Creek waste rock – blockage of outlet and failure of valley on road side leading to temporary blockage of the channel in the canyon; and Porcupine Creek waste rock – continued instability and movement) none of the consequences were evaluated because no significant effects were identified or the failure effect likelihood was unlikely or very unlikely. These decisions were made during the workshop discussions based on the judgement of the participants.

The five critical failure modes that were identified are (three refer to the waste rock piles and two to the tailings):

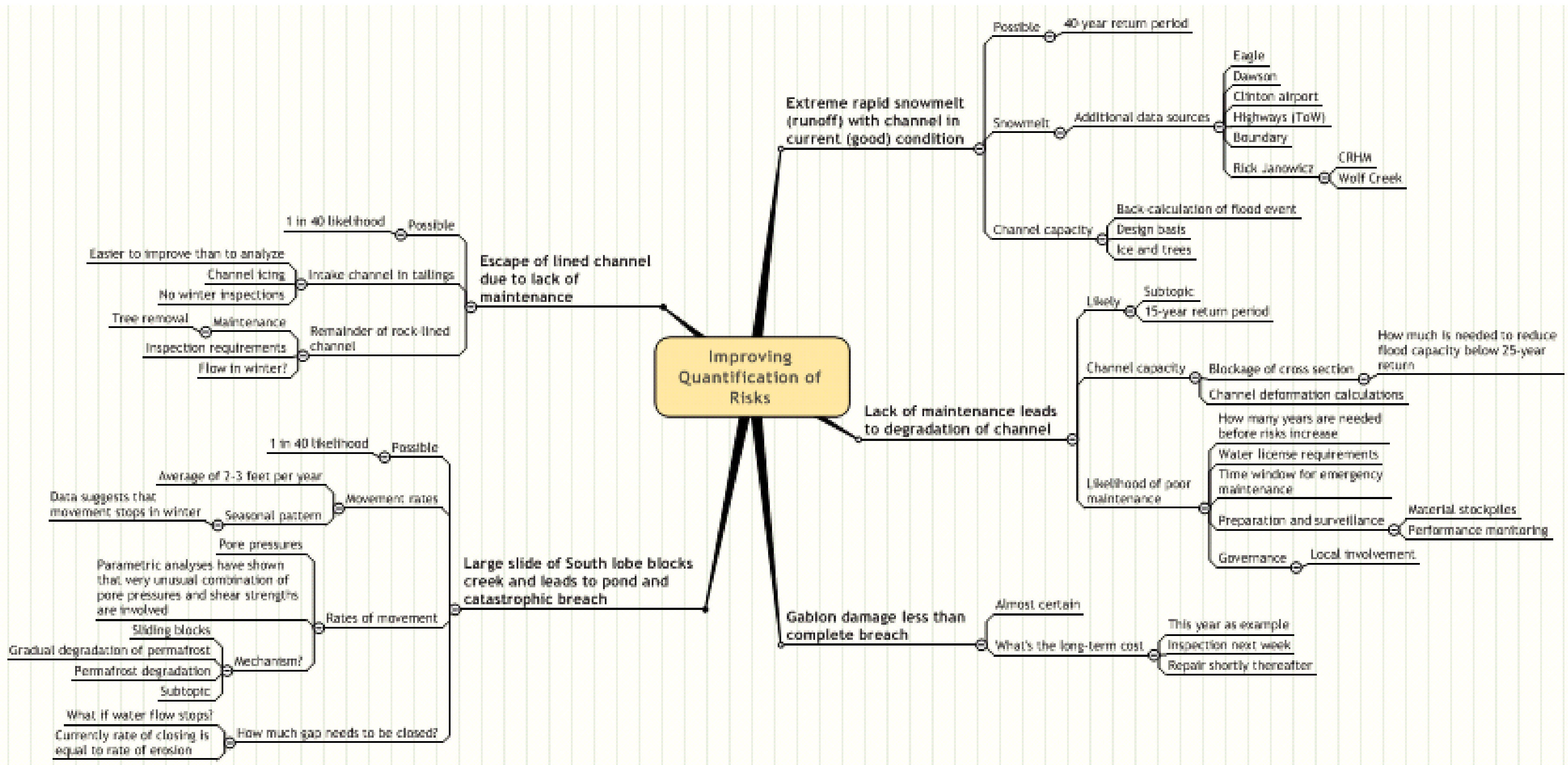
- Extreme rapid snowmelt (runoff) in Clinton Creek with channel in current (good condition) resulting in severe damage to the gabions leading to a breach of the upper channel and lowering of the lake outlet;
- Lack of maintenance of gabion structures leads to degradation of Clinton Creek channel so that a less extreme flood causes a breach of the upper channel and rapid lowering of the lake outlet;
- Gabion damage results in a less than complete breach which results in increased maintenance costs and periodic repairs;
- Large slide of South Lobe tailings blocks Wolverine Creek and leads to upstream ponding and catastrophic breach; and
- Escape of Wolverine Creek from the lined channel below the tailings lobes due to lack of maintenance resulting in rapid downcutting of the tailings material underlying the channel.

These failure modes were discussed and mindmaps were developed for them to outline the components of the process for better quantification of these risks. Figure 4 presents the outcome of these discussions. An evaluation of the risks for each of these failure modes is presented in the next section.

Table 1: Risk Review

	FMEA											Criticality										Comments
Area	Failure Mode	Effect	Effect	Environmental Impact						Legal Obligations			Consequence Costs			Community/Media /Reputation			Human Health and Safety			
			Likelihood	S	L	Risk	S	L	Risk	S	L	Risk	S	L	Risk	S	L	Risk	S	L	Risk	
CC Waste Rock	Extreme rapid snowmelt (runoff) with channel in current (good) condition	Breach of upper channel. Rapid lowering of lake. Release from lake. Inundation of valley. Material redistribution. Downstream sediments.	Possible	Moderate	Possible	Moderately High	Moderate	Possible	Moderately High	Moderate	Unlikely	Moderate	Major	Possible	High	Moderate	Possible	Moderately High	Major	Unlikely	Moderately High	Gabions are designed for 25-year flood. The gabions have survived, with some damage, arguably a 50-yr plus flood; but that might be just good luck. High flows would only happen during freshet when people are less likely to be in the creek (unlikely impact to human health and safety); but salmon fry could be present (possible environmental impact).
	Lack of maintenance leads to degradation of channel	Less extreme flood leads to breach of upper channel. Rapid lowering of lake. Release from lake. Inundation of valley. Material redistribution. Downstream sediments.	Likely	Moderate	Likely	Moderately High	Moderate	Likely	Moderately High	Moderate	Possible	Moderately High	Major	Likely	High	Moderate	Likely	Moderately High	Major	Unlikely	Moderately High	
	Blockage of outlet	Water cuts new channel around first gabion structure	Unlikely	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
	Blockage of channel in canyon	Breach of lake outlet.	Very Unlikely	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
	Failure on valley or road side leading to temporary blockage of channel in canyon	Subsequent breach of blocked area and washout of sediments etc.	Possible	Moderate	Unlikely	Moderate	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
	Continued movement	Continuing maintenance requirements and periodic replacement of gabions	Almost Certain	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Moderate	Likely	Moderately High	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
	Continued movement	Chronic sediment loading downstream	Almost Certain	Minor	Almost Certain	Moderately High	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
	Gabion damage less than complete breach	Increased maintenance costs and periodic repairs	Almost Certain	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Moderate	Almost Certain	High	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
Porcupine Creek w/r	Continued instability and movement	No significant effects	Likely	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
Snowshoe w/r	Slope failure	Material slumps into Clinton Creek valley.	Possible	Low	Possible	Low	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
Tailings	Movement of North lobe	Valley bottom raises up and creates pond. Ongoing erosion of tailings.	Almost Certain	Minor	Almost Certain	Moderately High	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	Tailings settle in pond.
	Large slide of North lobe blocks creek and leads to pond and catastrophic breach	Tailings release sufficient to go beyond pond. Similar to 1974 event. Significant washout of tailings and deposition all along Wolverine Creek. Fibres and tailings along Clinton Creek.	Unlikely	Moderate	Unlikely	Moderate	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Moderate	Unlikely	Moderate	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
	Movement of South lobe	Ongoing erosion and deposition of tailings	Almost Certain	Minor	Almost Certain	Moderately High	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
	Large slide of South lobe blocks creek and leads to pond and catastrophic breach	Flow escapes rock-lined channel and cuts down into underlying tailings. Significant washout of tailings and deposition all along Wolverine Creek. Fibres and tailings along Clinton Creek.	Possible	Major	Possible	High	Major	Possible	High	Insignificant	Very Unlikely	#N/A	Major	Possible	High	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
	Escape of lined channel due to lack of maintenance	Rapid downcutting of underlying tailings. Rapid retrogressive erosion. Significant washout of tailings and deposition all along Wolverine Creek. Fibres and tailings present along Clinton Creek.	Possible	Major	Possible	High	Major	Possible	High	Insignificant	Very Unlikely	#N/A	Major	Possible	High	Insignificant	Very Unlikely	#N/A	Insignificant	Unlikely	#N/A	
	Continuing rill erosion exposes fresh tailings to wind	Dust emmissions	Possible	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Moderate	Very Unlikely	Low	
General Site	Fall or driving vehicles, ATV's, snow machines etc. over high slope		Almost Certain	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Major	Unlikely	Moderately High	
	Swimming in pits		Possible	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Major	Unlikely	Moderately High	
Equipment	People playing on equipment		Likely	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Insignificant	Very Unlikely	#N/A	Major	Unlikely	Moderately High	

Figure 4: Clinton Creek Improving Quantification of Risks



6 Further Review of Risk Ratings

6.1 Introduction

For the next step in improving the quantification of the risks the following approach was followed:

- Development of a more detailed description of the failure mode and the items identified on Figure 4, clearly identifying all assumptions;
- Compilation and evaluation of the available data in more detail;
- Quantitative evaluation as appropriate to provide further information about the failure mode;
- Comment on the degree of confidence provided by this extra information and evaluation; and
- Comparison between the failure mode and effect likelihood and risk estimated from this more detailed evaluation with the outcomes of the workshop; identify whether any of the levels of risk identified during the workshop should be increased or decreased.

6.2 High Runoff in Clinton Creek from Snowmelt – Gabions in Good Condition

6.2.1 Failure Mode and Effect from FMECA

Extreme rapid snowmelt results in runoff while the channel is in good condition as is currently the case (after recent maintenance). This rapid runoff results in severe damage to the gabions leading to a breach of the upper channel and a rapid lowering of the lake outlet. Water is released from the lake inundating the valley and redistributing the eroded materials. The effect is considerable sediment loading downstream reaching the Fortymile River via Clinton Creek (9 km) and potentially the Yukon River (5km downstream on the Fortymile River).

During the workshop the likelihood of occurrence of this failure mode was estimated as possible, i.e. equivalent to a 40 year return period. This combined with a major cost consequence ($2.5 to $10 million) resulted in this failure mode being assigned a high risk. It was further commented that: *Gabions are designed for 25-year flood. The gabions have survived, with some damage, arguably a 50-yr plus flood; but that might be just good luck. High flows would only happen during freshet when people are less likely to be in the creek (unlikely impact to human health and safety); but salmon fry could be present (possible environmental impact)*.

6.2.2 Site Data and Evaluation

This section summarizes the applicable site hydrological data, flows and erosional effects of extreme events as well as the design and performance of the gabion structures. An evaluation of the data is presented at the end of the section.

Golder (1977) presented the flow data in Table 2 for maximum discharges in Clinton Creek above Wolverine Creek. The first two data points are from the Water Survey of Canada flow records in Appendix A while the last data point was computed from observed flow depths. The first two data points are before any mining operations at Clinton Creek. The 1975 data most probably reflect the failed condition with Hudgeon Lake in place; therefore restricted flows in Clinton Creek. Note that the watershed area upstream of the confluence of Clinton Creek and Wolverine Creek is somewhat larger than that upstream of the outlet of Hudgeon Lake. This may contribute to these high values of computed maximum discharges.

Table 2: Recorded and Computed Maximum Discharges in Clinton Creek above Wolverine Creek (Golder, 1977)

Year	Discharge (cfs)	Discharge (m^3/sec)
1964 (May)*	13,400	379
1965 (July)*	4,780	135
1975 (Spring)**	5,000	141

* Recorded at Gauge Station 9EC-1 (refer to Appendix D)

** Computed discharge, based on the following verbal information from G.R. Vincent: Spring 1975, outlet from Hudgeon Lake: The discharge flowed through two culverts under the main access road. The culverts were each 6 ft diameter. At the time of the peak discharge there was 7 ft head at the upstream end of the culverts. For computing discharge it was assumed that the length of each of the culverts was 60 ft.

After formation of Hudgeon Lake the flow into Clinton Creek was through an outlet that traverses a plug of waste rock. The total depth of Hudgeon Lake was estimated at about 27m and the volume at about 12 million m^3, it was noted that the accuracy of this measurement is within ± 50 percent (Royal Roads, 1999). Using 1:50,000 scale NTS map sheets from 1959 UMA independently estimated the volume of the current lake level to be 9.4 million m^3 (AECOM, Overview report, 2009).

The formation of Hudgeon Lake drowned the vegetation in the valley. This dead vegetation contributes to the debris that was in the lake discharge. Some of the debris material is quite large such as tree trunks that float to the surface of the lake.

The drainage area of Clinton Creek upstream of the Hudgeon Lake outlet is 117 km^2 (however, the UMA (2000) report on page 19 refers to it as 111.9 km^2). The discharges for various return periods shown in Table 2 were calculated for the 117 km^2 drainage (UMA, 2003).

Table 3: Discharges for Clinton Creek at the Hudgeon Lake Outlet (UMA, 2003)

Return Period	Discharge (m^3/sec)
25-year flood	28.9
50-year flood	33.8
100-year flood	39.0
200-year flood	44.5

One comment in a handout at the 2009 FMECA workshop (Clinton Creek Slope Area Discharge 2009) states that: “the highest flow event recorded prior to some of the extreme events was 15 m^3/sec on May 7, 1979”.

Over the last 30 years a number of extreme run-off events were estimated based on flow depths observed after the events, these are described in various reports (Clinton Creek Slope Area Discharge 1989, Clinton Creek Slope Area Discharge 2009; AECOM overview report, 2009; Geo-Engineering, 1998). The events listed in the various reports are as follows:

- Large runoff event 1988 – 62 m^3/sec
- Large precipitation event June (?) 1997 – 65 m^3/sec
- Spring freshet 2009 – 56.95 m^3/sec

Comments in various reports describe the concerns as well as the observed conditions following these events. Specifically:

- "Recognizing the potential for a breach of the waste rock plug at the outlet from Hudgeon Lake, the mining company initiated erosion control measures that included excavation of a channel and the installation of four culverts and a rock apron at the northeast edge of the waste rock where the access road to the mill crosses the channel. In 1981, rock weirs were constructed in the channel downstream of the culverts. During the 1982 freshet, the creek escaped the armoured channel section and downcut into the north valley slope. The armoured section was reconstructed in 1984 and during a high flow event in 1997, was almost completely destroyed", AECOM Overview Report, July 2009.
- The 1997 "flood exceeded flow stages monitored in the past. It was estimated that the flow reached a level some 1.8 m above "normal" stage at the gauge station. The Clinton Creek channel was significantly modified and driftwood, leaves and mud deposited on the banks clearly outlined the extent of this event". During the 1998 inspection it was observed that: "downcutting of the channel bottom and lateral erosion is evident between the remaining lake outlet armoured plug and the floodplain downstream from the Clinton Creek waste rock dump. It is the writer's opinion that the armoured section of the lake outlet could be destroyed by any significant flood event", Geo-Engineering, July 1998. "The 1997 flood triggered major changes in the gradient and configuration of the Clinton Creek channel. Main changes occurred between the Hudgeon Lake outlet and the Wolverine/Clinton Creek junction. Further degradation (downcutting, as well as lateral erosion) of the channel was observed during the July 2000 site visit", Geo-Engineering, August 2000.

The data in Figure 5 shows that about 50m (in horizontal direction) of material was removed from the waste rock plug above elevation 405m between 1984 and 1999, while about 100m of material was removed at elevation 400m. This is a significant amount of material and led to fears "that the retrogressive incising would rapidly continue and a full breach of the lake outlet could be triggered", AECOM (2009).

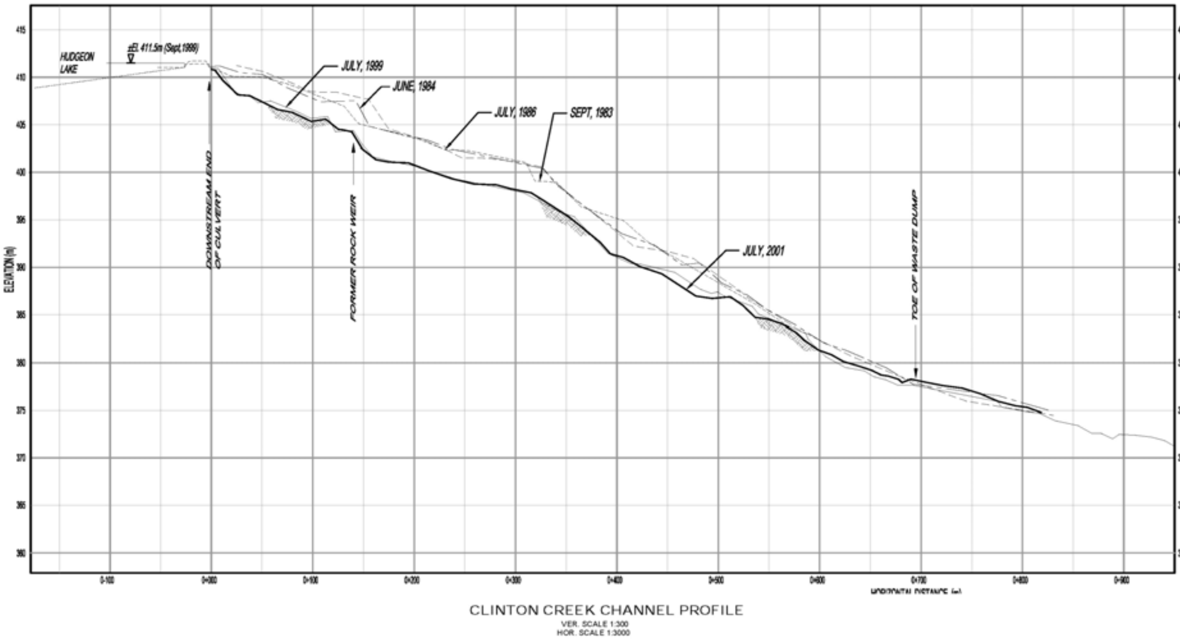


Figure 5: Clinton Creek Channel Profiles (UMA, 2003)

It is interesting to note that the calculated extreme floods of 1988, 1997 and 2009 all exceeded the estimated 200-year flood in Table 3. This may reflect the uncertainty in hydrological information or channel flow conditions that were different than those assumed in these calculations, e.g. flows from freshet concentrated in the northern part of the channel because of ice left in the southern part.

In 2000 UMA (Risk Assessment Report) emphasized the need to develop a more permanent remediation approach to the Hudgeon Lake outlet and channel section over the waste rock plug. It was stated that: “A catastrophic dam breach would most likely involve a failure mode where a partial or complete breach of the waste rock channel blockage at the Hudgeon Lake outlet occurs. The breach could develop as a result of a channel blockage from debris or ice, continued incising of the channel bottom, a significant overtopping event or any combination of the above. It must be recognized however, that the failure mode could be triggered at any time in the foreseeable future and is not considered susceptible to any particular precipitation event, i.e. a relatively minor inflow could trigger the failure mechanism necessary to initiate a breach”.

Following careful evaluations the gabion structures presently in place were designed and constructed during the construction seasons of 2002 to 2004. The following describes the design criteria used in the design of these structures (UMA, Environmental Liability Report, 2003):

> “Based on the relatively coarse channel bed material, a design flow velocity of 1.1 m/s was selected to design the stabilized channel. The estimated 25-year flood (Q=28.9 m^3/sec) was used for the design of the channel stabilization works for the waste rock pile. However, the discharge of a 25-year flood at the Hudgeon Lake outlet will be smaller due to the flood

> attenuation caused by Hudgeon Lake, resulting in a higher level of protection than indicated by the 25-year return period. Based on the design discharge of 28.9 m^3/sec, 3H:1V side slopes and a grade (between drop structures) of 0.1%, the new channel geometry will require a bed width of 7m and a flow depth of 2m. With the dimensions of the individual gabion baskets used for the drop structures (3.0m long, 1.0m wide, 0.5m high), the freeboard at the control structures will be approximately 0.2m which is sufficient to confine the 50-year flood within the new channel cross-section".

These structures were significantly damaged during the estimated 56.95 m^3/sec flood in 2009. Repairs and modifications to the structures were done in fall 2009.

The following estimate of the average sediment load that could be present in water if the outlet of Hudgeon Lake fails and the waste rock pile plug is cut down, was made using conservative assumptions. The slope angle of the rock pile plug into the lake was estimated at 20 degrees based on extending the above water level rock pile slope given in Figure 2 of the Conceptual Design Report (UMA, 2002). The slope of the channel downstream of the outlet is about 3 degrees (refer to Figure 5 above). Using these values and assuming a 10m top width of the outlet, the length of the erosional cut through the rock pile can be estimated, assuming that the present location of the channel is followed. The width of the erosional section is assumed to be 40 m. The average sediment load is calculated for a 2.5m increment in incised depth and the amount of water in the lake in this interval (based on the Royal Roads, 1999 report); Table 4 presents the calculations for the estimated sediment load. The estimated sediment load ranges from 0.3 to 1.66 percent and it is considered that this sediment load can be easily carried by the flowing water if a breach should occur.

If the volume of Lake Hudgeon is lower than that obtained by Royal Roads (as indicated by the UMA estimates), the incremental water volumes flowing from the pond in Table 4 will be reduced while the sediment loads will increase. A sediment load equal to double that shown in Table 4 is still realistic in the rapidly flowing water.

Table 4: Estimating the Sediment Load during Subsequent 2.5m Erosional Depths

Depth from Lake Surface (m)	Incremental water volume (10^6 m^3)	Width of Breach (m)	Length of Breach (m)	Volume of Rock Eroded (m^3)	Sediment Load (%)
2.5	2.2	40	65	6,500	0.3
5.0	2.7	40	119	11,900	0.44
7.5	1.4	40	174	17,400	1.24
10	1,8	40	228	22,800	1.27
12.5	1,7	40	283	28,300	1.66

Costs since completion of construction in 2004 for maintaining the gabion structures (including surveying, engineering interpretation, design adjustments and repairs) are roughly $450K[1]. However, costs for 2009 make up more than half of that amount due to the extreme damage to the gabions that year. Considering this, and also the intended normalization of the survey/inspection/repair program (every two years unless otherwise necessary) it is projected that the costs for maintaining the gabions will average approximately $45K every year based on current prices. Additional contingency funding for maintenance should be held for extreme events. With current rock pile movement and structure deformation rates, the gabions are expected to require total replacement every 15-20 years at a cost of $2 to 3 million. Associated costs, such as maintaining site access and government project management are estimated with project management at about 15%, and road repairs and other miscellaneous tasks at $5K/year, which form an additional, on-going cost.

Given all the information above, the cost per year of maintaining the gabion structures is therefore estimated as:

Survey/Engineering – $20K

Repairs – $25K

Road access and Misc related work – $5K

Replacement cost – $100k to $250K

Project Management at 15%

Total – $172.5 to $345K per annum

6.2.3 Updated Failure Description

Key points, assumptions and consequences of this failure mode

The following are the key points and assumptions of this failure mode:

- High discharge resulting from rapid snowmelt or high precipitation event;
- Debris and ice included in the discharging water;
- Damage and removal of top gabions resulting in damage to rest of gabions;
- Sudden release of water from Hudgeon Lake erodes the waste rock resulting in extra sediments loads of 1 to 3 percent;

[1] Costs incurred related solely to the gabions are not exact as the contracts for surveying and engineering involved additional work on Wolverine Creek and sometimes related site work that would not form part of long-term management of the structures. The cost estimates above take this into account and are adjusted to reflect work on the Clinton Creek structures.

- Some sediment settles at the flatter area near the confluence with Wolverine Creek while the rest is transported to the Fortymile River;
- Rebuilding of an engineered channel necessary after the event; and
- Consequences (refer to Table 1): consequence costs due to reconstruction of the engineered channel results in high risk, environmental impact results in moderately high risk, special considerations – mitigatable impact to traditional land use results in moderately high risk, community/media/reputation results in moderately high risk, human health and safety as a result of danger to somebody present during flood results in moderately high risk; legal obligations results in moderate risk.

Update Description

Following the rapid snowmelt of a larger than normal snow load or a large precipitation event in the Clinton Creek catchment upstream of the Hudgeon Lake outlet, flood debris including driftwood, tree trunks and ice damages the outlet structure of Hudgeon Lake sufficiently to physically move the upper layers of gabions downstream. This results in the rapid release of water from the lake further downcutting the outlet. This sets up a domino effect that damages the remaining gabions and downcutting continues as more water is released from Hudgeon Lake. As the erosional depth increases the sidewalls will become unstable and may collapse into the breach thereby temporarily blocking the breach. However, once the water level in the lake increases this material may be washed out and erosion may continue.

It is recognized that the gabions consist of multiple vertical layers and that this will mitigate against failure. The failure mechanism described above may be too simplistic.

An alternate failure mechanism may occur when debris blocks the outlet and the gabions remain stable. However, the water overtops the outlet and erodes the north bank, which is opposite the main waste rock dump, thereby cutting a new channel around the gabions (similar to the 1982 failure). This channel gets wider as more water is released and the flow ultimately undercuts the gabions thereby resulting in complete failure of the gabion structures.

The sediments in the water will be carried downstream and some of it will settle in the flatter area of the floodplain near Wolverine Creek, however some will remain as suspended load. This is consistent with observations during construction of the gabion structures. A cofferdam was constructed to allow the gabion construction to be accomplished in a dry streambed. When the cofferdam was removed at the end of construction the remaining soil and rock materials were taken up in the water flowing over the outlet and remained as suspended load, black in color as a result of graphite in the waste rock, until it reached the Fortymile River. Here the material rapidly mixed into the much larger flow of the Fortymile River.

In the case of the larger flows resulting from breaching the outlet releasing approximately 2×10^6 m^3 of water in about 1 hour, the flow rate in Clinton Creek could be up to about 500 m^3/sec (it is uncertain whether the Clinton Creek channel can actually convey this flow). The discharge data for the Fortymile River in Appendix A indicating a flow rate of about 1,200 m^3/sec in the early summer means that it will be difficult to effectively mix the Clinton Creek flow without causing sedimentation in the river. If the failure takes place over a longer period of time, say 4 to 6 hours, then mixing will result in much lower, but potentially visible, sediment loads in the Fortymile River.

Uncertainties and Information Needs

The following uncertainties remain and collecting further information listed may help to resolve these uncertainties:

- The high risk rating refers to consequence costs in the $2.5 to $10 million range. This cost range is realistic for complete reconstruction or repair of the engineered channel through the remains of the rock pile after the flood event; however, it is uncertain that reconstruction would be undertaken.
- The environmental impacts and special considerations consequences have not been established with a high degree of reliability; further toxicity and other environmental evaluations are underway.
- Flows higher than the projected 200 yr flood event have been estimated three times in 21 years. This leads to high uncertainties about the site hydrology and the flood occurrences especially as nobody was on site to observe the local conditions. Further hydrology evaluations and sensitivity analyses may help resolve this issue.

6.2.4 Conclusions

Site specific information that was reviewed above indicates that the failure mode as identified during the FMECA workshop could be possible. The Hudgeon Lake outlet could be eroded significantly by a large flood event. The return period of the flood event that can cause such a failure is uncertain and may be higher than the 40 years assumed at the time of the workshop, although uncertainties remain about the site hydrology and flood events. The extent, impacts and consequences of this failure event are less certain. The risk ranking of high for cost consequences assumes a major engineering design and construction project. The overall risk classification could be lower than decided at the workshop but high uncertainties remain; it is concluded that the rating for this risk should remain high.

6.3 Lack of Maintenance of Gabions Leads to Channel Degradation

6.3.1 Failure Mode and Effect from FMECA

Lack of timely maintenance leads to degradation of the gabion structures in the upper channel so that a less extreme flood causes a breach of the upper channel and a rapid lowering of the lake outlet. Water is released from the lake inundating the valley and redistributing the eroded materials. The effect is considerable sediments downstream reaching Fortymile River via Clinton Creek (9 km) and potentially the Yukon River (5km downstream on the Fortymile River).

During the workshop the likelihood of occurrence of this failure mode was estimated as likely, i.e. equivalent to a 15 year return period. This assumption was based on the fact that the gabions, construction of which was completed in 2004, were damaged during the 2009 break up. Although the engineered channel is designed for the 25-year flood, a higher discharge event seemed to have damaged the gabions significantly. If there is no maintenance following such an event and a second or third similar event occurs in the 15 year period then the consequence cost to repair the engineered channel could be major ($2.5 to $10 million) resulting in a risk rating of high for this failure mode.

6.3.2 Site Data and Evaluation

The review of data above indicates that the two discharge events which occurred in 1997 and 2009 both exceeded the estimated 200 year return event. These extreme discharge events were spaced about 10 years apart. The gabion structures (installed 2002-2004) were designed for the 1 in 25 year event and were seriously damaged during the 2009 event. Lesser damage was repaired in 2005 and 2007, with baskets being refilled and a few modifications made to the design of the structures based on performance evaluation by the engineers.

It is expected that if the gabions are significantly damaged and not repaired promptly, further impacts to the integrity of the gabions can occur due to high flow events during the annual freshet. Floating debris, including ice and logs from Hudgeon Lake will most likely further damage the gabion baskets and dislodge the rocks in the baskets. Such ongoing impacts can ultimately result in extensive failure of the gabions.

It is not possible to determine whether the gabions will fail from the top, i.e. near the Hudgeon Lake outlet or the bottom, i.e. from the lowest gabion uphill. In the former case the failure could occur as a steady lowering of the outlet due to erosion. Large volumes of water can flow from Hudgeon Lake and will erode the rock pile plug materials.

In the case of an uphill moving failure it is expected that it may take longer to initiate the complete failure of the gabions, however part of the rock pile plug will start eroding uphill towards the Hudgeon Lake outlet. The outlet area may fail rapidly once it is reached and a deep failure section may develop.

It is also possible that debris can get caught easier in the damaged gabions and that it will cause overtopping of the gabions and erosion of the waste rock north of the present channel location. As described above this erosion may ultimately result in complete failure of the Hudgeon Lake outlet.

6.3.3 Updated Failure Description

Key Points, Assumptions and Consequences of this Failure Mode

The following are the key points and assumptions of this failure mode:

- Damage to gabions is not repaired and similar, or lower, flood events that can cause ongoing damage to the gabions are repeated regularly over a 15 year period.
- Significant debris and ice contribute to the damage of the gabions.
- Due to subsequent flood events the channel fails completely.
- Due to ongoing damage the intermittent release of water from Hudgeon Lake erodes the waste rock resulting in extra sediments loads of 1 to 3 percent.
- Some sediment settles at the flatter area near the confluence with Wolverine Creek while the rest is transported to the Fortymile River.
- Rebuilding of an engineered channel necessary after a 15 year period for continued performance of the structures.
- Consequences (refer to Table 1): consequence costs due to reconstruction of the engineered channel results in high risk, environmental impact results in moderately high risk, special considerations – mitigatable impact to traditional land use results in moderately high risk, community/media/reputation results in moderately high risk, human health and safety as a result of danger to somebody present during flood results in moderately high risk; legal obligations results in moderately high risk.

Updated Description

The gabions are damaged either by a large event, or by several years of lesser, but progressive damage. The damage is not repaired. The damaged gabions are subjected to impact from debris (ice and possibly tree trunks) that is released from Hudgeon Lake. This debris results in a blockage with high local flows resulting in further damage to the gabions or erosion of the north bank of the channel. Such damage will ultimately result in rendering the gabions ineffective and cause erosion to the underlying waste dump plug materials. Erosional forces will remove waste rock materials and deposit it downstream in the flatter parts of the Clinton Creek channel, while some sediment will be transported to Fortymile River and ultimately to the Yukon River depending on the amount of mixing in the Fortymile River as determined by the relative flow rates in each.

Uncertainties and Information Needs

The following uncertainties remain and collecting further information listed may help to resolve these uncertainties:

- The high cost risk rating refers to consequence costs in the $2.5 to $10 million range. This cost range is realistic for complete reconstruction or repair of the engineered channel through the remains of the rock pile after the flood event; however, it is uncertain that reconstruction will be undertaken, particularly if maintenance was not being done.

- The environmental impacts and special considerations consequences have not been established with a high degree of reliability; further toxicity and other environmental evaluations are underway.
- High uncertainties remain about the site hydrology and the flood occurrences especially as nobody was on site to observe the local conditions during previous flood events. Further hydrology evaluations and sensitivity analyses may help resolve this issue.

6.3.4 Conclusion

It is possible that sufficiently high discharge events could take place in the next 15 years that can result in failure of the gabions if necessary maintenance is not completed in a timely manner, or not done at all. The failure likelihood discussed at the FMECA workshop of once in 15 years seems appropriate for this failure mode. Such a failure will result in high engineering and construction cost as indicated above. The risk level selected during the workshop therefore seems appropriate.

6.4 Gabion Damage less than Complete Breach

6.4.1 Failure Mode and Effect from FMECA

The gabions undergo damage less than a complete breach which results in increased maintenance costs and periodic repairs.

During the workshop the likelihood of occurrence of this failure mode was estimated as almost certain, i.e. it is expected to occur more than once every 5 years. This combined with a moderate cost consequence ($500,000 to $2.5 million) resulted in a high risk for this failure mode.

6.4.2 Site Data and Evaluation

The review of data above indicates that the discharge events that occurred in 1988, 1997 and 2009 might have exceeded the 200 year return event. These extreme discharge events were spaced about 10 years. The gabion structures were designed for the 1 in 25 year event and were damaged during the 2009 event but it did not result in a complete breach.

The gabion flood control structures were completed in 2004, the damage therefore occurred less than 5 years after completion.

6.4.3 Updated Failure Description

Key Points, Assumptions and Consequences of this Failure Mode

The following are the key points and assumptions of this failure mode:

- The gabion structures are required into the future to control discharges from Hudgeon Lake.

- The need for complete replacement of the gabion structures are determined by movements of the rock pile and performance of the gabions.
- Significant debris and ice contribute to the damage of the gabions.
- The gabions were significantly damaged in 2009 but did not result in a complete breach.
- Gabion structures are repaired and there is ongoing monitoring of and maintenance to the stream channel.
- Consequences (refer to Table 1): consequence costs due to reconstruction of the engineered channel results in high risk, the other consequences were not evaluated because they were considered to result in lower risks.

Updated Description

The gabions undergo damage less than a complete breach but the damage results in increased maintenance cost. It is expected that the gabions will almost certainly undergo significant damage costing less than $500,000 in 5 years and likely more than $500,000 in 15 years. Ongoing inspections, monitoring, maintenance and some repairs will be required.

Uncertainties and information needs

The following uncertainties remain and collecting further information may help to resolve these uncertainties:

- The high cost risk rating refers to consequence costs in the $500,000 to $2.5 million range. This cost range is realistic for ongoing inspections, monitoring, maintenance and repair of the engineered channel. However, there are uncertainties about exact costs of such activities and the associated time period.
- High uncertainties remain about the site hydrology and the flood occurrences especially as nobody was on site to observe the local conditions during previous flood events. Further hydrology evaluations and sensitivity analyses may help resolve this issue.

6.4.4 Conclusion

The likelihood of this failure mode identified during the FMECA workshop may be too high, i.e. considerable damage to the gabions every 5 years. Maintenance costs could be in the range indicated above (i.e. $500,000 to $2.5 million) if damage occurs, but more likely in a 15 year period rather than 5 year period. Therefore, because of the lower likelihood it is concluded that the risk rating of this event is moderately high.

6.5 Large slide of South Lobe of Tailings Blocks Wolverine Creek

6.5.1 Failure Mode and Effect from FMECA

Large slide of the South Lobe blocks Wolverine Creek and leads to upstream ponding and catastrophic breach. The effects will be that the flow escapes the rock-lined channel and cuts down into underlying tailings. This will result in significant washout of tailings and deposition all along Wolverine Creek with fibres and tailings along Clinton Creek.

During the workshop the likelihood of occurrence of this failure mode was estimated as possible, i.e. equivalent to a 40 year return period. This combined with an assumed major environmental impact, special consideration, i.e. assumed impact on traditional land use and resources as well as major cost ($2.5 to $10 million) to reconstruct the area downstream of the breach, including the stabilized channel below the tailings lobes, resulted in a high risk for this failure mode.

6.5.2 Site Data and Evaluation

The South Lobe of the tailings failed in 1974 following considerable time-dependent displacement down the hill; it has undergone continuous displacements since then. Some remedial activities, such as removal of tailings in the toe area to reduce loads, were undertaken, however, due to ongoing movements more material has been deposited in the area of Wolverine Creek increasing the height of the tailings. Movement monitoring shows that during the last 10 years the surface movement of the South Lobe has been at a rate of 2 to 3 ft/year. The frequency of movement monitoring (currently every two years) does not allow for determining the seasonal distributions of the movements, e.g. whether the movements stop during the winter. The movement of the South Lobe is determined by the present site conditions including pore pressure and shear strength of the underlying foundation materials (UMA, 2003).

The failure mechanism resulting in the initial failure of the South Lobe is thought to have involved the build-up of excess pore pressures within the active layer of the foundation soils beneath the tailings in a small draw in the hill side. The downward movements of the tailings were attributed to the thaw-consolidation process of the permafrost beneath the tailings as observed from thermistor installations in the tailings pile. Once the toe reached Wolverine Creek ongoing erosion of the toe caused unloading of the toe resulting in ongoing movements (Golder, 1978).

In general, the displacements varied along the length of the lobe with the largest movements occurring at the toe and small displacements occurring near the top of the slope (UMA, Env. Liability Report, June 2003).

UMA (2002) indicates that the alignment and elevation of Wolverine Creek was about 25m further to the east and about 13m higher than it was before the South Lobe failed. The section of the South Lobe shown in Figure 6 also indicates that the slope of the foundation is about 18 degrees.

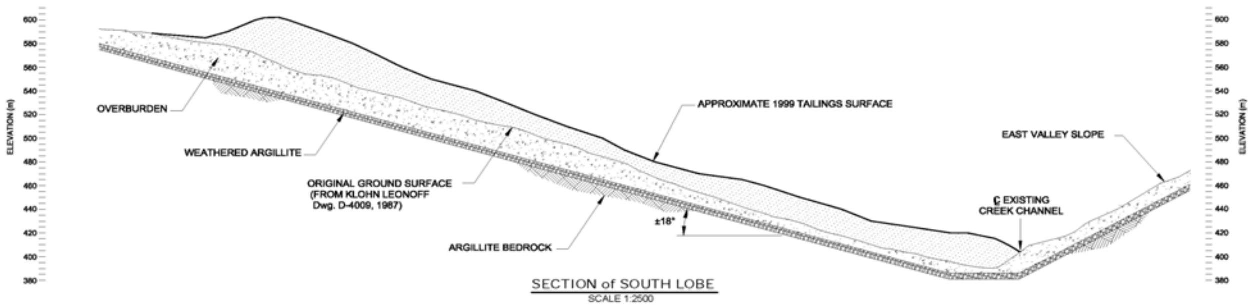


Figure 6: Section through Tailings South Lobe UMA (2002)

Horizontal movements for the South and North Lobes of the tailings were measured from 1978 to 1986 and again from 2004 to present. The horizontal movement rates for the South Lobe are shown in Table 6 below.

Table 5: Summary of Horizontal Movement Rates – South Lobe (UMA 2003, 2009 June Monitoring)

a) 1978 to 1986

Monitor Location	Maximum Rate		Minimum Rate	
	metres/yr	Year Reported	metres/yr	Year Reported
Upper slope	0.76	Aug 1981	0	Summer 1980
Mid-slope	6.6	June 1986	1.1	Summer 1978
Lower slope	4.9	June 1986	0.65	June 1982

b) 2004 to 2008

Slope Area	Annual Horizontal Movement Rates (m/yr)					Rate Change Last 2 Surveys
		Monitoring Period 1984	Monitoring Period 2004-2005	Monitoring Period 2005-2006	Monitoring Period 2006-2008	
Upper	Average	0.5	0.13	0.10	0.07	-0.03
(2 monitors)	Maximum	-	0.18	0.18	0.09	-0.09
	Minimum	-	0.09	0.02	0.05	0.03
Mid	Average	7.00	0.76	0.43	0.33	-0.10
(12 monitors)	Maximum	-	0.93	0.75	0.58	-0.17
	Minimum	-	0.35	0.04	0.03	-0.01
Lower	Average	-	0.45	0.48	0.38	-0.10
(14 monitors)	Maximum	2.80	0.66	0.81	0.62	-0.19
	Minimum	0.50	0.05	0.03	0.02	-0.01

The drainage area of Wolverine Creek upstream of the tailings is 29 km^2. The discharges for various return periods are shown in Table 7.

Table 6: Discharges for Wolverine Creek at the Tailings (UMA, 2003)

Return Period	Discharge (m^3/sec)
25-year flood	10.0
50-year flood	12.2
100-year flood	14.9
200-year flood	17.3

A review of the tailings stability is presented by UMA (2003), it is noted that "the position of the composite failure surface is not precisely known but it is likely located within the overburden and/or weathered argillite layer, as evidenced by overburden material pushed up in front of the advancing north and south lobes".

The following text taken from UMA (2003) describes the stability analyses and results:

> "The existing failure surface was assumed to be approximately parallel with the original ground surface and within a weak layer at a shallow depth in the foundation soil. Residual friction angles of shearing resistance were used for the tailings, overburden and weathered argillite, based on the direct shearing results. The piezometric level within the overburden and weathered argillite bedrock was modeled using the pore water coefficient R_u, which is the ratio of pore water pressure to overburden pressure. A 3m deep, water filled tension crack located on the surface of the tailings was assumed in the model. Sensitivity analyses were subsequently carried out to determine the R_u value necessary to provide a factor of safety of 1.0. The resulting R_u values for the North and South Lobes are 0.22 and 0.33, respectively.
>
> "The analysis indicates that a combination of residual shear strengths and high pore-water pressures in the overburden material are required to achieve a FS of unity. This observation provides further evidence that unique geological conditions, in particular a shallow weak layer within the overburden, are responsible for continued movement of the tailings pile. Almost certainly, disturbance of the thermal regime, in particular thawing of the permafrost resulting from the placement of tailings over the valley slope has been a contributing factor. Although detailed knowledge of the changes to the thermal regime that occurred during and following active placement of tailings is not known, it is possible that the thermal regime has still not reached a state of equilibrium".

It is unclear what mechanism could trigger a rapid failure of the South Lobe in the future. Potential contributing factors include:

- A larger sliding block higher up on the slope does not slide down with the mass but hangs up and then becomes suddenly dislodged resulting in an impact load to the rest of the failure mass. While there are some indications that the rate of slope movement is faster near the bottom than the top of the slope, this difference is not expected to cause significant "gaps" between the two sections of the South Lobe. Furthermore, Figure 6 above indicates that the natural slope angle is constant and that the tailings depth increases slightly towards the top. The latter, because the thicker tailings will have a higher downslope force, will further mitigate against “gaps” being formed between the upper and lower parts of the sliding tailings mass. Also, the tailings are already buttressed against the eastern slope so that any increased downward movement of the tailings will move the stream higher up against this slope. It is concluded that this trigger mechanism is not realistic.

- Further gradual degradation of the permafrost results in significant reduction of the foundation material shear strength. The recent horizontal movement data indicates that there has been a deceleration of the movement, most probably caused by a stabilization of the foundation temperatures. It is therefore expected that this mechanism will not develop.
- Sudden degradation of the permafrost resulting in the same outcome. Based on site observations to date this mechanism is also highly unlikely.
- Seismic event triggering a rapid movement of the South Lobe. A review of seismic events exceeding magnitude 4 in a 100 km radius of the site since 1984 results in 5 earthquakes of magnitude 4.0 to 4.8 between 1986 and 2004. The horizontal movements of the tailings are measured once every two years and this makes it impossible to relate the horizontal movements of the South Lobe to seismic events. However, there are no clear accelerations observed in the horizontal movements. It is therefore unclear whether a seismic event of similar magnitude could trigger a rapid movement of the South Lobe.

At the present rate of movement the creek erodes away all the material that fails from the face of the moving mass. From observations during a field visit in August 2009, the height of the failing face is in the order of 6m. It would be important to know how long the flow in the creek can significantly reduce or stop before the face moves far enough to close the gap. The flow rates during the winter months are not measured but indications are that they may reduce significantly from that during the late summer.

6.5.3 Updated Failure Description

Key Points, Assumptions and Consequences of this Failure Mode

The following are the key points and assumptions of this failure mode:

- The consequence severity assumes that the rock lined channel would be rebuilt.
- Asbestos in the tailings is assumed to be an environmental problem if transported in large amounts downstream at one time.
- Consequences (refer to Table 1): environmental impact results in high risk, special considerations – significant temporary impact to traditional land use results in moderately high risk, consequence costs due to reconstruction of the engineered channel results in high risk.

Updated Description

The South Lobe of the tailings move faster than the flow in Wolverine Creek can erode the materials, either as a result of a rapid movement or as a result of low flow in the channel. The flow in Wolverine Creek is blocked and ponding occurs upstream between the South and North Lobes and potentially upstream of the North Lobe. Surface water overtops the South Lobe tailings and is cut down rapidly resulting in rapid breach of the tailings as a result of the high flow. Water escapes the rock lined channel downstream of the South Lobe and cuts down the underlying tailings. A significant volume of tailings is washed downstream resulting in fibres and tailings along Clinton Creek with some reaching the Fortymile River.

Uncertainties and Information Needs

The following uncertainties remain and collecting further information listed may help to resolve these uncertainties:

- The high cost risk rating refers to consequence costs in the $2.5 to $10 million range. A better estimate of these costs should be made.
- Environmental concerns about asbestos tailings if transported downstream, further evaluations are underway.
- Assumption that locals value the immediate area for traditional uses and would be concerned by more tailings down the creek bed, even though it is already filled with tailings. Develop a better understanding of the traditional uses of the site.

6.5.4 Conclusion

The slow creep movements of the South Lobe are controlled by the combination of pore pressure and shear strength conditions in the underlying foundation materials. Tailings material has completely overrun the original streambed and has moved against the east wall of the drainage further stabilizing the mass. The likelihood of a rapid failure, as discussed during the workshop, does not seem to be possible. Therefore the risk of this failure mode is less severe than high. The consequences of a failure are also not clear as the environmental impacts of asbestos release in water must still be defined; similarly the special considerations and cost consequences are not clear. It is concluded that the risk rating for this failure mode should be lower than identified in the workshop.

6.6 Escape of Flow from Wolverine Creek due to Lack of Maintenance

6.6.1 Failure Mode and Effect from FMECA

Flow escapes from the lined channel due to a lack of maintenance of the inlet conditions. The effect is a rapid downcutting of the tailings material underlying the channel and rapid retrogressive erosion that results in significant washout of tailings and deposition along Wolverine Creek. Fibres and tailings also present along Clinton Creek.

During the workshop the likelihood of occurrence of this failure mode was estimated as possible, i.e. equivalent to a 40 year return period. This combined with a major environmental impact, special consideration, i.e. impact to traditional land use and resources as well as major cost ($2.5 to $10 million) resulted in a high risk for this failure mode.

6.6.2 Site Data and Evaluation

Partial re-grading of the north and south tailings lobes was done in 1978 and 1979 in an attempt to stabilize the tailings, this was unsuccessful. In 1978, a rock-lined channel with a series of rock weirs was constructed in Wolverine Creek across the tailings immediately downstream of the South Lobe. The slope of this system is 8 percent. Figure 7 below shows a plan of the rock-lined channel.

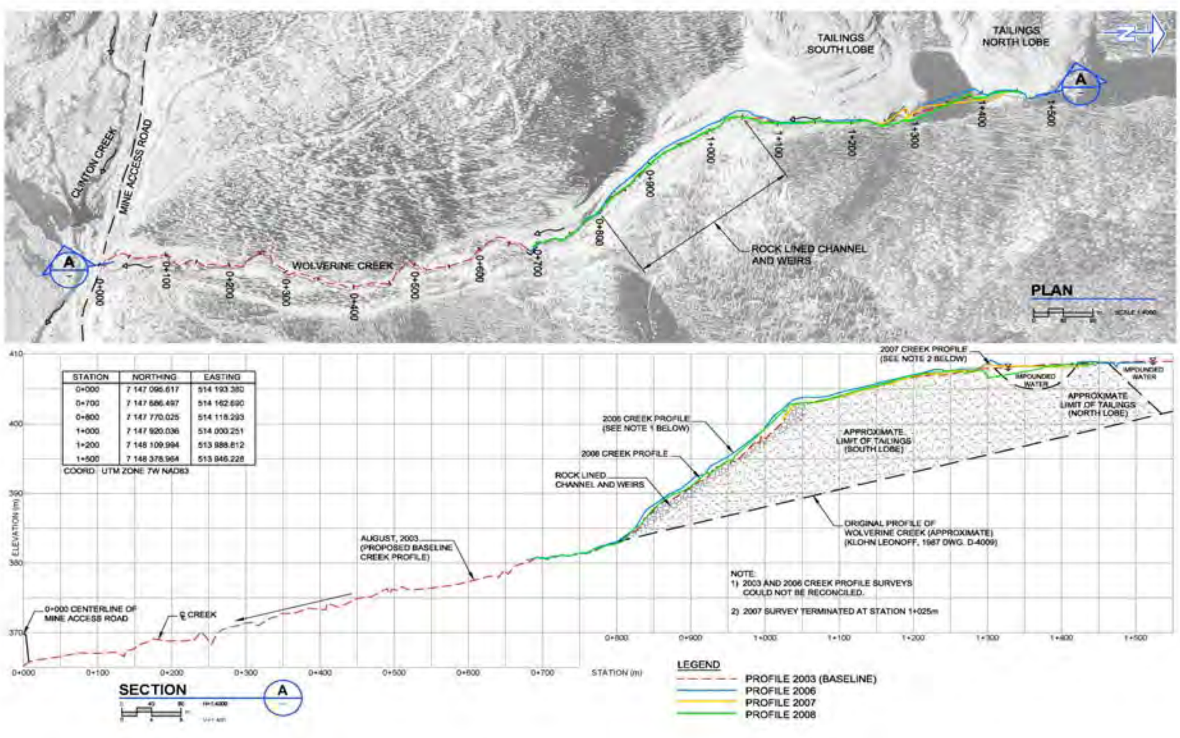


Figure 7: Plan and Section of Rock-lined Channel Downstream of Tailings South Lobe (UMA, 2008)

In 1981 Hardy found that the outfall immediately downstream of the last weir in the rock-lined channel was unprotected and that retrogressive erosion was occurring such that the structural integrity of the last three weirs was poor. A recommendation was made to install a rip-rap apron downstream of the last weir and to rehabilitate the damaged weirs. Over time the rock weirs have become flattened and brush has established along the channel banks and in the channel, which make the rock weirs barely recognizable in the field. These measures have performed well to date although some deterioration was noted during recent site visits. In 2007 recommendations were made to remove the trees and brush growing within the channel and this was done (AECOM, 2008 Performance Monitoring).

The flow in Wolverine Creek downstream of the South Lobe was assessed in more detail following the 2007 site inspection. The cross-section of the valley floor in this area is convex and at several locations along the rock-lined channel the top of the bank is located higher than the intersection of the tailings and the creek valley sides. As a result, in the event the creek flow overtops the top of bank of the creek channel, it is more likely that the creek flow would cut a new channel along the valley side and not return to the existing channel at the end of the flood event (AECOM, 2008 Performance Monitoring).

The analyses show that a discharge of 16.6 m^3/s, equivalent to the 200-year flood, did not overtop the rock-lined channel bank. The potential for break-out from the channel is relatively low as the creek channel is stable and not eroding. The calculated flow velocity in the channel varied from 1.1 to 3.8 m/s and the flow was supercritical along most of the reach of the rock-lined section. The lowest flow velocities were calculated along the upstream and downstream ends of the rock-lined section (AECOM, 2008).

As a result of these analyses AECOM (2008) states that: “If localized erosion is identified and the placement of additional riprap is contemplated, it is important that the available channel depth from top of bank is not reduced. For example, if an 800 mm layer of Class 2 riprap is placed on the creek bed the water level in the creek may increase a corresponding amount and could cause an overtopping of the creek banks. Therefore it is important that any creek channel revetment be designed rather than simply placed without any assessment of how it may affect the creek flow at that location”.

6.6.3 Updated Failure Description

Key Points, Assumptions and Consequences of this Failure Mode

The following are the key points and assumptions of this failure mode:

- Risk assumes channel control structures would be rebuilt.
- Assumes asbestos tailings are a problem if transported in large amounts downstream at one time.
- Consequences (refer to Table 1): environmental impact results in high risk, special considerations – significant temporary impact to traditional land use results in moderately high risk, consequence costs due to reconstruction of the engineered channel results in high risk.

Updated Description

Flow escapes from the rock-lined section of the channel as a result of poor inlet conditions, overtopping resulting from dense vegetation or very high flows. The stream rapidly cuts through the tailings and erodes a large volume of tailings depositing fibres and particles along Clinton Creek and potentially reaching the Fortymile River.

Uncertainties and Information Needs

The following uncertainties remain and collecting further information listed may help to resolve these uncertainties:

- The high cost risk rating refers to consequence costs in the $2.5 to $10 million range. A better estimate of these costs should be made.
- Environmental concerns about asbestos tailings if transported downstream, further evaluations are underway.
- Assumption that locals value the immediate area for traditional uses and would be concerned by more tailings down the creek bed, even though it is already filled with tailings. Develop a better understanding of the traditional uses of the site.

6.6.4 Conclusion

The rock-lined channel has performed well since its construction in 1978. Maintenance, such as vegetation removal and some repair to the rock lining, has been done since 1978. Hydraulic modeling of the stream indicates that a 1:200 year flood can safely pass through the rock-lined channel, even though a large part of it will be subject to supercritical flow. Based on the observations of field performance as well as the analysis results, it is concluded that the estimate of a 40 year failure return period may be too conservative; however, it is expected to be between a 40 year and a 200 year failure return period due to the ongoing deterioration of the rock-lined channel if there is not ongoing maintenance. Using this return period the risk of this failure mode is considered to be moderately high to high; however, the severity of the consequences have considerable uncertainty as mentioned above in 6.6.3., so this risk could be different pending investigations into these uncertainties.

The inlet conditions for the rock lined channel can be different during the winter due to ice build up; no winter inspections of the site occur and it is therefore not known what the flow in Wolverine Creek is during the winter. Regular inspections of the channel inlet conditions should be part of the long-term maintenance. Regular removal of trees along the rest of the channel is also required.

7 Conclusions and Recommendations

A review of risks for the Clinton Creek Mine review identified five risk areas worthy of further investigation:

- Extreme rapid snowmelt (runoff) in Clinton Creek with channel in current (good condition) resulting in severe damage to the gabions leading to a breach of the upper channel and lowering of the lake outlet;
- Lack of maintenance of gabion structures leads to degradation of Clinton Creek channel so that a less extreme flood causes a breach of the upper channel and rapid lowering of the lake outlet;

- Gabion damage results in a less than complete breach which results in increased maintenance costs and periodic repairs;
- Large slide of South Lobe tailings blocks Wolverine Creek and leads to upstream ponding and catastrophic breach; and
- Escape of Wolverine Creek from the lined channel below the tailings lobes due to lack of maintenance resulting in rapid downcutting of the tailings material underlying the channel.

A more detailed review of these risk areas concluded that they are correctly rated as “high” with the exception of a large slide of the South Lobe that can be rated as “moderately high”.

The ratings of “high” risk are based on cost consequences (all five), environmental consequences (two) and special considerations (two). The ratings of cost consequences are well-supported by available information; however, the environmental consequences of tailings and sediment release from the site remain a subject of investigations. There is ongoing work to evaluate the uncertainties associated with asbestos impact on aquatic resources, and potential sedimentation effects of the waste rock or tailings in the event of a large failure as well as chronic erosion of the piles.

A future extension of the risk evaluation for the site is the consideration of possible different options to deal with waste rock and tailings failure risk at the site. Different methods or approaches to dealing with these two site features may have greater long-term stability and/or less maintenance, which would reduce consequence costs while not raising (and possibly reducing) risks under other consequence categories. Or, some options could significantly reduce risk under other consequence categories. However, such risk reduction would have to be weighed against the capital costs of any new approach as costs of significant construction activities may be so large as to negate the benefits. This will likely be a key consideration for the evaluation of any proposed options.

The following recommendations arise from the risk ratings and the subsequent review.

Recommendations:

1. Complete work to elucidate the potential environmental effects of the failure modes (i.e. significant washout of waste rock or tailings into the stream system).

2. Undertake investigation of local and traditional usage of the area to better inform classification of risk under special considerations.

3. Re-evaluate site risks when information under 1 and 2 is available.

4. Extend risk evaluation to the proposed closure options. Determination the potential for risk reduction in enacting each closure options compared to the existing site risk.

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Appendix A
Risk Review Preparation

Clinton Creek Risk Review – Guide for Participants

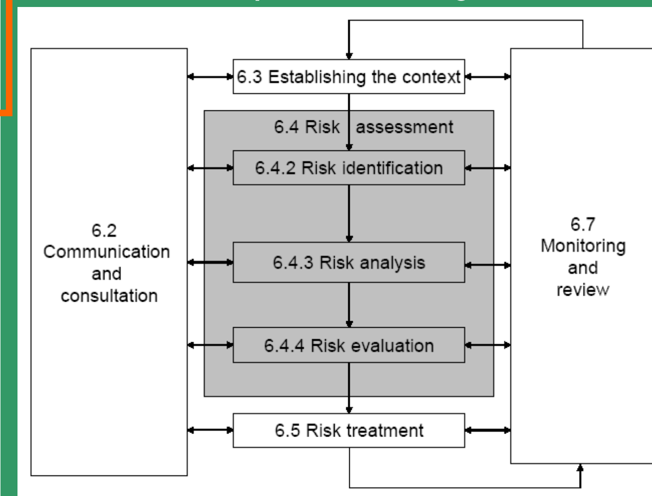
Project Objectives

- One of the steps in evaluating remediation strategies for the Clinton Creek site; it will be used to inform the decision-making process.

Goals for September 3, 2009

- Identify and evaluate risks associated with the current conditions at the Clinton Creek site
- Further discuss high risk failure modes

ISO 31000 Steps in Risk Management



Scope

- Clinton Creek site (pits, roads, water bodies(?) waste rock and tailings).
- Upstream including Hudgeon Lake as well as North Lobe of tailings.
- Infrastructure and use of area (e.g. road, hunting, exploration).
- Temporal – present site conditions.

Context

- Define objectives, goals and scope (see above)
- Invite participants representing Yukon Government, site experts, First Nation and Canada
- Assemble background documents and make them available to participants
- Assemble previously completed relevant risk registers
- Identify facilitator – Dr. Dirk Van Zyl, Professor of Mine Life Cycle Systems, UBC
- Select method – Failure Mode , Effect and Criticality Analysis (FMECA)

ISO 31000 Vocabulary

Risk – Effect of uncertainty on objectives
Event – Occurrence or existence of a particular set of circumstances
Consequence – Outcome of an event or change in circumstances affecting the achievement of objectives
Likelihood – the chance of something happening
Level of Risk – Magnitude of a risk measured in terms of the combination of consequences and their likelihood
Risk Criteria – terms of reference against which the significance of a risk is evaluated

Example of steps followed in the FMECA method (refer to worksheet example for a different project below; note that the nomenclature in the attached tables will be used for Clinton Creek)

- Group divides system into components (1) and analyzes risk one component at a time (2).
- Individual proposes or is asked to discuss a "risk event" or "Failure Mode". (3)
- Same individual presents what he/she thinks will be the "Effects" and their "Likelihood". These are discussed by the group and a consensus description is recorded. (4) (5)
- The group then discusses the "Consequences" . (6)
- The "Level of Risk" is evaluated by comparing "Consequences" and their "Likelihood" to "Risk Criteria" (7)
- The "level of confidence" in the assessment is discussed and recorded. (8)
- Additional notes are provided for subsequent uses of the results. (9)
- All steps are recorded in a "Risk Register" such as the one below.

FAILURE MODES AND EFFECTS ANALYSIS (FMEA) WORKSHEET - SITE X TAILINGS

AREA (1)	ID	FAILURE MODE (3)	EFFECTS (4)	PROJECT STAGE	LIKELIHOOD (5)	ALT. LIKELYHOOD	CONSEQUENCES (6): DIRECT COST	ENVIRONMENTAL IMPACTS	SUBSISTENCE USE	REGULATORY & LEGAL	PUBLIC CONCERN & REPUTATION	PUBLIC SAFETY	LEVEL OF CONFIDENCE (8)	HIGH CONCERN ISSUE	MITIGATION / COMMENTS (9)
Main Dam (2)	A.1	Deep seated (into foundation) static stability failure													Need continued attention in further design
	A.1.1	- Large Breach: Failure would intersect the tailings, cut into the unfrozen shale - possibly along a weak zone and daylight in the toe area along a non-circluar slip surface. Likelihood increases with dam height, steepening. More likely to occur when facility is first loaded with tailings/water.	Catastrophic failure, breaching of structure, release of tailings to downstream creek system, fine tailings could wash for a long distance downstream	CO/EO	NL		E	E	E	E	E	L	H		This failure mode is normally addressed as part of routine dam design studies.

5 (NL=not likely)
7 (colours indicate risk levels)

Important note:
The FMECA method requires definitions of the "Consequences" important to the company, the "Likelihood" categories and "Risk Criteria".
We will use the definitions in the INAC Register, (including the higher cost factors)

Individual preparation

- Review site materials on SharePoint site
- Add to ist of "failure modes"

Clinton Creek Risk Review – Consequence-Severity Matrix

Note that UKHM and Mt. Nansen are used as examples only to help clarify the descriptions.

Consequence Categories	Very Low	Minor	Moderate	Major	Critical
1. Environmental Impact	No impact.	Minor localized or short-term impacts.	Significant impact on valued ecosystem component.	Significant impact on valued ecosystem component and medium-term impairment of ecosystem function.	Serious long-term impairment of ecosystem function.
		UKHM: Ice plug release at Onek 400 adit	*UKHM: Tailings dam breach*	*Mt. Nansen: Failure of Main Dam leads to release of contaminated water & tailings into Victoria Creek*	
2. Special Considerations	Some disturbance but no impact to traditional land use.	Minor or perceived impact to traditional land use.	Some mitigatable impact to traditional land use.	Significant temporary impact to traditional land use.	Significant permanent impact on traditional land use.
		UKHM: Ongoing release of zinc into wetland areas			*Mt. Nansen: Tailings dam breach*
3. Legal Obligations	No non-compliance but lack of conformance with departmental policy requirement. Informal advice from a regulatory agency. No land claim or other agreement.	Technical/Administrative non-compliance with permit, approval or regulatory requirement. Warning letter issued. Land claim or other agreement requires the Crown to satisfy administrative obligations (e.g. notification).	Breach of regulations, permits, or approvals (e.g. 1 day violation of discharge limits). Order or direction issued. Land claim or other agreement requires the Crown to respond, but no time frame is specified.	Substantive breach of regulations, permits or approvals (e.g. multi-day violation of discharge limits). Prosecution. Land claim or other agreement requires the Crown to exercise its obligations within a specified time frame (i.e. 2-5 years)	Major breach of regulation – wilful violation. Court order issued. Land claim or other agreement requires the Crown to exercise its obligations within a specified short time frame (i.e. 1-2 years)
			Mt. Nansen: Hydrocarbon from historical spills seeps into receiving water	*UKHM: Tailings dam breach*	

Clinton Creek Risk Review – Consequence-Severity Matrix (Cont)

Consequence Categories	Very Low	Minor	Moderate	Major	Critical
1. Consequence Costs	< $100,000	$100,000 - $500,000	$ 500,000 - $2.5 Million	$2.5 - $10 Million	>$10 Million
		Mt. Nansen: Erosion leads to loss of spillway		*Mt. Nansen: fire in mill leads to loss of power and treatment*	*UKHM: Tailings dam breach leading to tailings release*
2. Community/ Media/Reputation	Local concerns, but no local complaints or adverse press coverage.	Public concern restricted to local complaints or local adverse press coverage.	Heightened concern by local community, criticism by NGOs or adverse local /regional media attention.	Significant adverse national public, NGO or media attention.	Serious public outcry/demonstrations or adverse International NGO attention or media coverage.
				UKHM: Tailings dam breach	
3. Human Health and Safety	Low-level short-term subjective symptoms. No measurable physical effect. No medical treatment.	Objective but reversible disability/impairment and /or medical treatment injuries requiring hospitalization.	Moderate irreversible disability or impairment to one or more people.	Single fatality and /or severe irreversible disability or impairment to one or more people.	Multiple fatalities.
			UKHM: Public access to boneyards leads to injury	*UKHM: Snow machine accident on waste rock leads to fatality*	*UKHM: Vehicle accident on poorly maintained road leads to multiple fatalities*

Clinton Creek Risk Review – Likelihood Table

Likelihood	Descriptor 2	Frequency Descriptor	Probability of Occurrence Over Twenty Years	Probability of Occurrence in Any One Year
Almost Certain	Happens often	High frequency (more than once every 5 years)	98%	17.8%
Likely	Could easily happen	Event does occur, has a history, once every 15 years	75%	6.7%
Possible	Could happen and has happened elsewhere	Occurs once very 40 years	40%	2.5%
Unlikely	Hasn't happened yet but could	Occurs once every 200 years	10%	0.5%
Very Unlikely	Conceivable, but only in extreme circumstances	Occurs once every 1000 years	2%	0.1%

Clinton Creek Risk Review – Risk Matrix

Likelihood	Consequence Severity				
	Low	Minor	Moderate	Major	Critical
Almost Certain	Moderate	Moderately High	High	Very High	Very High
Likely	Moderate	Moderate	Moderately High	High	Very High
Possible	Low	Moderate	Moderately High	High	High
Unlikely	Low	Low	Moderate	Moderately High	Moderately High
Very Unlikely	Low	Low	Low	Moderate	Moderately High

Appendix B
Clinton Creek Site Overview

Clinton Creek FMECA Workshop

September 3, 2009

Agenda

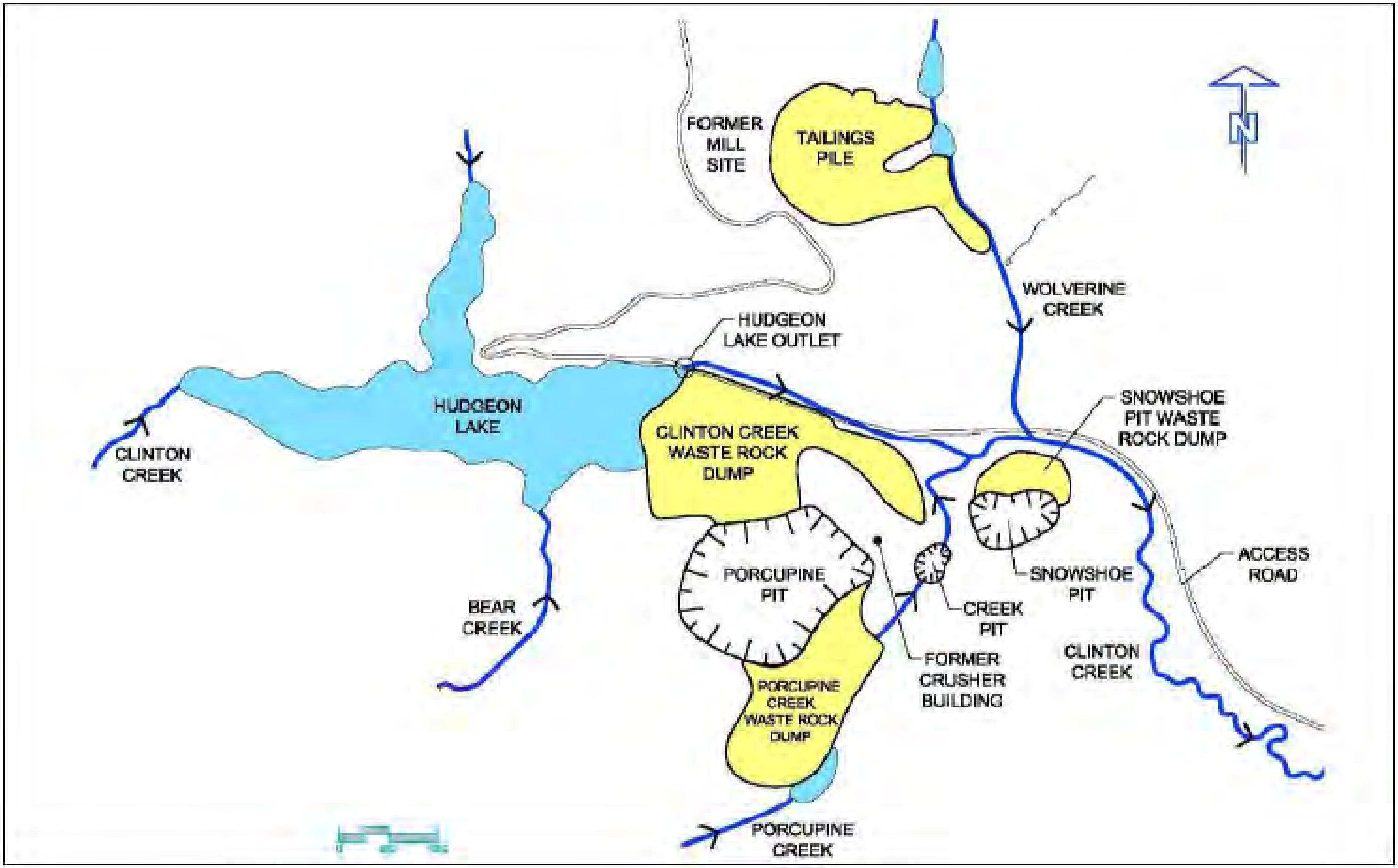
- 8:30 – 8:45 Introductions
- 8:45 – 9:15 Site Overview, Dirk van Zyl
- 9:15 – 9:30 Context, Rachel Pugh
- 9:30 – 9:45 FMECA Process Overview
- 9:45 – 10:00 Break
- 10:00 – 12:00 FMEA
- 12:00 – 1:00 Lunch
- 1:00 – 5:00 FMEA, FMECA, Discussions

Clinton Creek

Site Overview

FMECA Workshop, September 3, 2009

Former Clinton Creek
Asbestos Mine
Former Clinton Creek
Town Site
Mine Access Road
Forty Mile River
Yukon River
Top of the World Highway
Dawson City
Yukon-Alaska International
Border

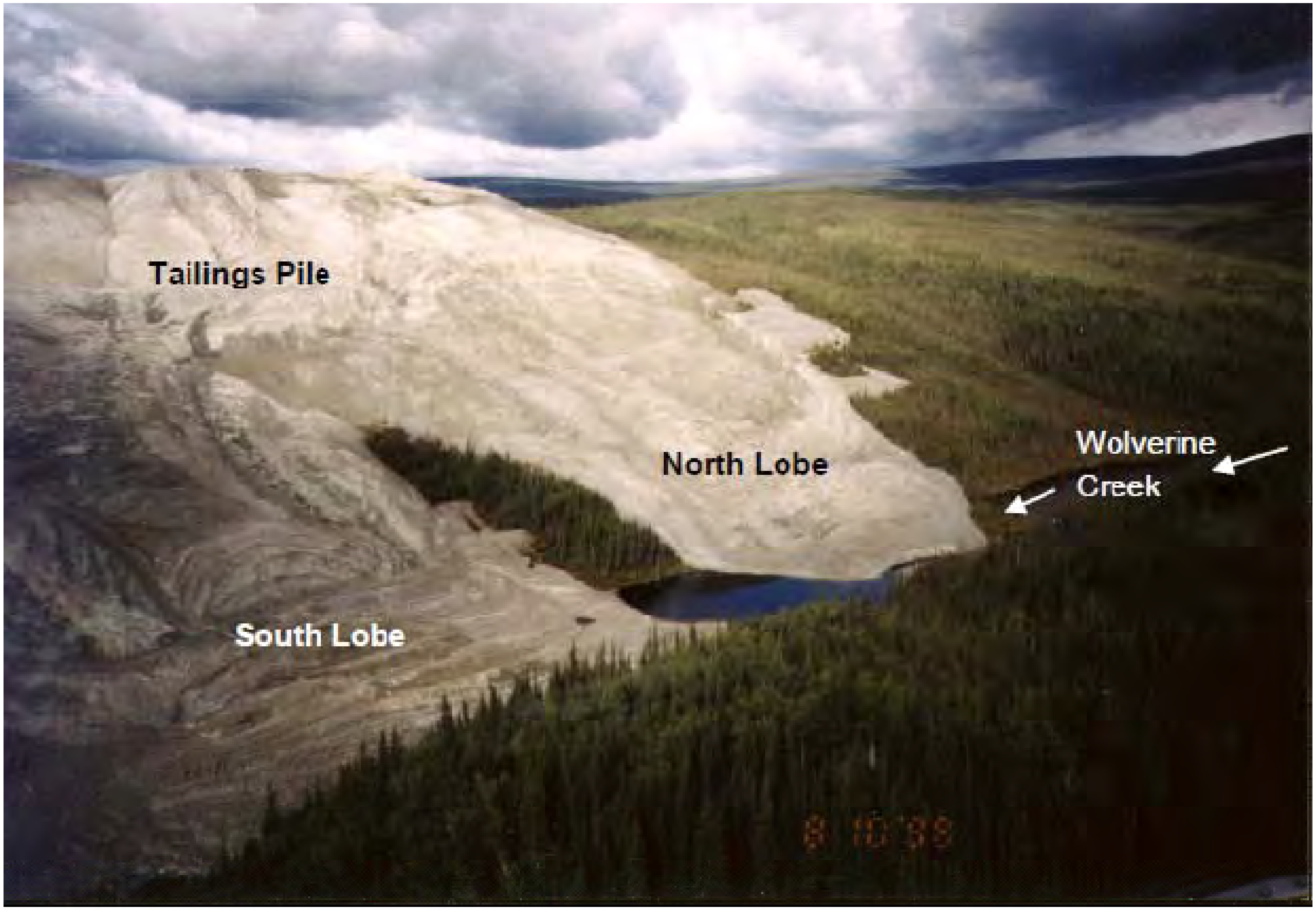

FORMER
MILL
SITE
TAILINGS
PILE
WOLVERINE
CREEK
HUDGEON
LAKE OUTLET
HUDGEON
LAKE
CLINTON
CREEK
CLINTON CREEK
WASTE ROCK
DUMP
SNOWSHOE
PIT WASTE
ROCK DUMP
PORCUPINE
PIT
BEAR
CREEK
CREEK
PIT
SNOWSHOE
PIT
ACCESS
ROAD
FORMER
CRUSHER
BUILDING
CLINTON
CREEK
PORCUPINE
CREEK
WASTE ROCK
DUMP
PORCUPINE
CREEK
N


Porcupine Pit
Clinton Creek
Waste Rock Dump
Rock Weirs
Outlet Culverts
Access Road to Mill
Hudgeon Lake

1985

August 2009


75
40-R



1998

August 2009

Appendix C
Context for Risk Review

Context for Risk Assessment Exercise

Putting the pieces together to inform decision making on a closure plan or long-term maintenance

Questions to be answered for decision making

Q1. What is the current state of the site?

- Waste Rock
- Tailings
- Hudgeon Lake
- Creeks
- Pits

→Well investigated and reported, ongoing regular monitoring

Questions to be answered for decision making

Q2. What effects are currently seen at the site?

- Fish Passage → reported by DFO
- Air quality/asbestos → investigated by UMA
- Changes in Water Chemistry ? → Minnow Environmental investigating
- Asbestos effects on aquatic life ? → Minnow
- Cost of site maintenance and project → costs to date and projected future costs

Questions to be answered for decision making

Q3. What are the present risks at the site?

High consequence risks – today's topic to discuss and expand, with follow-up by SRK

Questions to be answered for decision making

Q4. What are the potential effects if these events happened?

- Sediment effects on the ecosystem (Clinton Creek, Forty Mile, Yukon River – temporary, permanent?) → need to figure out what sort of projection is possible
- Remaining pile unstable, continued slide

Questions to be answered for decision making

Q5.

a) What possible options are there for addressing site risks and effects?

- e.g. Further stabilization of existing channel, make new channel, put everything back in the pit, etc.

b) How much is the risk level reduced by these measures?

c) What more information is needed for design?

Questions to be answered for decision making

Q6. Cost and feasibility of each option vs. status quo

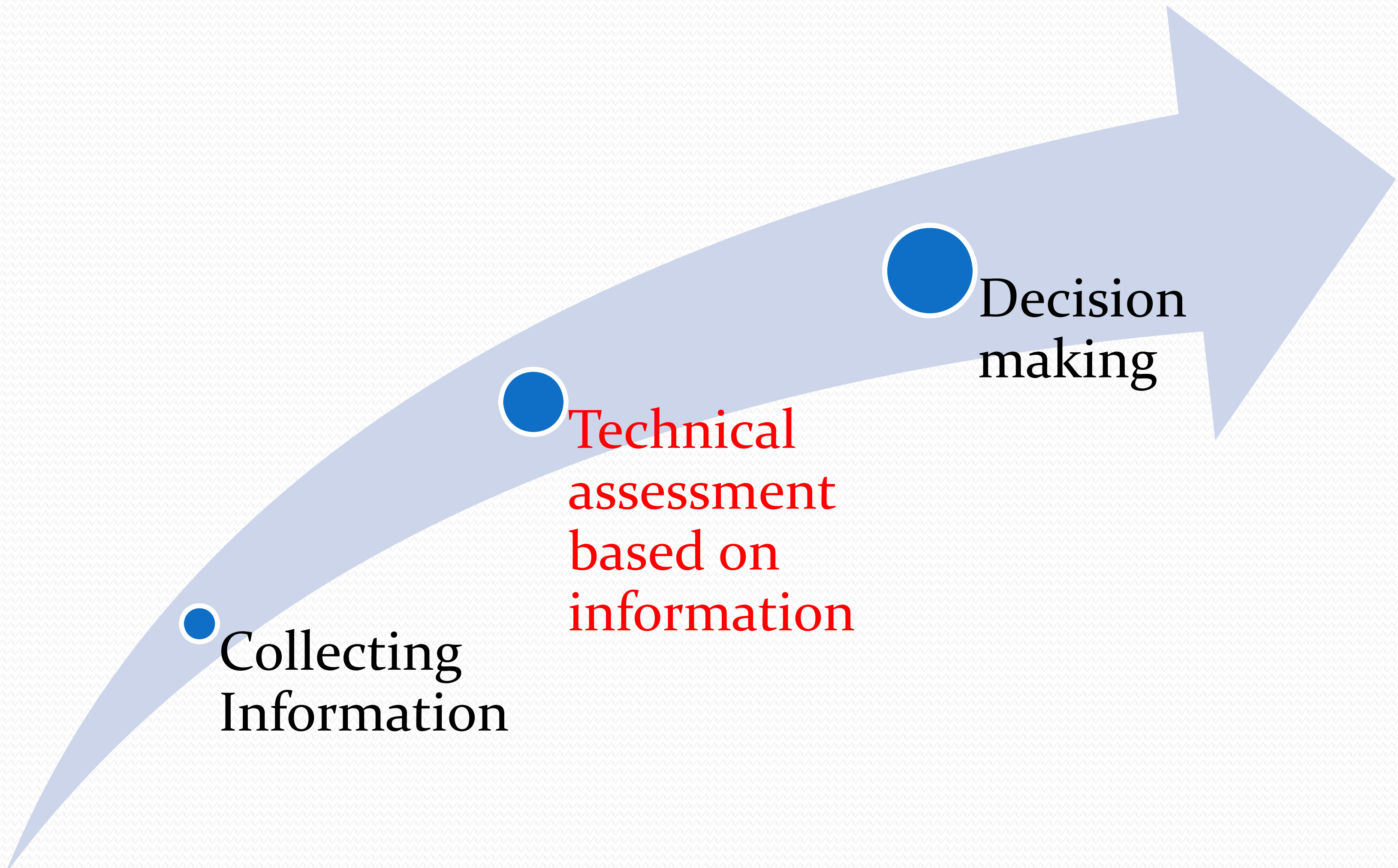
Two Decisions

1. Is further major action warranted? Can we do better than what we have now for a reasonable cost?

2. Which action is preferred?

We need to answer the first question before putting a lot of effort into details to support the second question.

Where are we now in this process?



Process Roadmap (Draft)

July - Overview Document Completed

- Summary of all information generated by technical studies over past 10 years under government care
- Summary of relevant and available information generated by operator during operations and shutdown in the 1970's/80's
- Summary of current state of site and residual site issues

July to October - Distribute Overview Document

- Discuss site issues/risks with GC/TH/YG
- Identify values/interests for site closure objectives
- Discuss closure planning framework with GC/TH
- Identify other landusers and interested parties

September /October- Risk Assessment Exercise and Aquatic Effects Results

- Risk Assessment workshop with SRK/AECOM/GC/TH/YG to identify low probability, high consequence risks and outstanding information needs
- Results from review of aquatic life data for CC - information needs and conclusions regarding aquatic toxicity of asbestos
- Effect of sediment release on aquatic habitat

- October /November Option Feasibility Assessment

- Tech Experts (SRK/AECOM) and Government (GC/TH/YG) walk through significant risks and possiblities for risk reduction, including consideration of costs
- Consider if further action warranted -
  - *proceed with detailed options paper or*
  - *initiate adaptive management plan*

If Major Options Considered

- Nov - commission options document
- Dec/Jan - subject options for Peer Review
- Jan/Feb - options evaluation and recommendation process

If Adaptive Management Plan

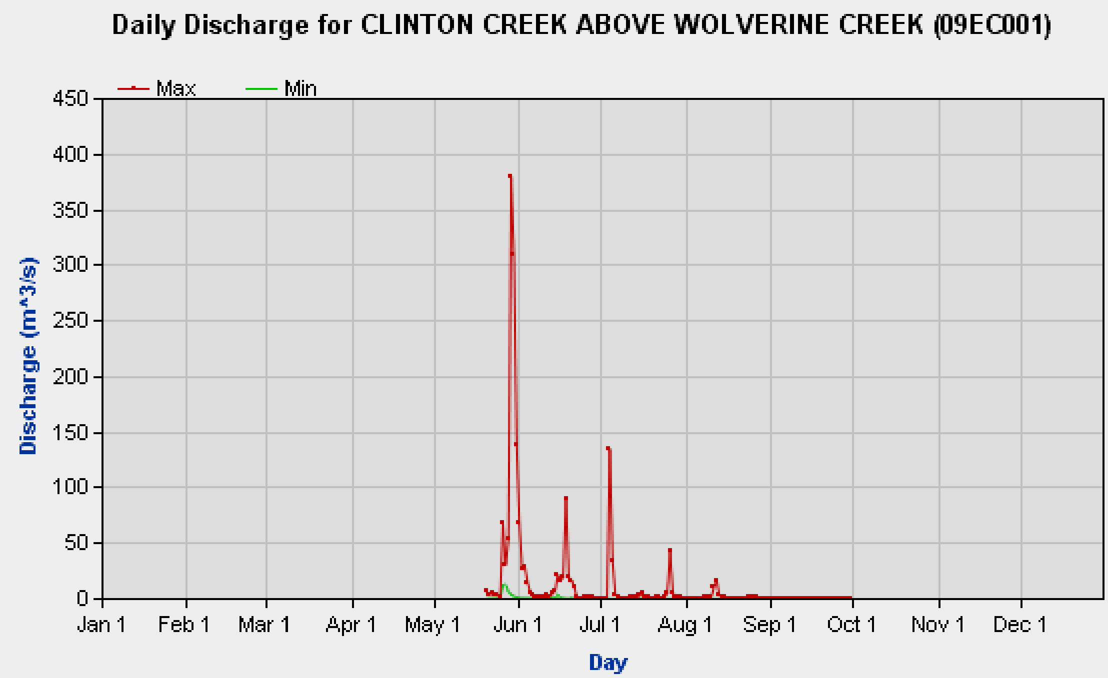
- Write up recommendations for decision
- Consider Peer Review
- Get Government approval and follow any regulatory processes for minor corrective actions

Appendix D

Surface Water Runoff – Clinton Creek and Fortymile River (from Water Survey of Canada)

CLINTON CREEK ABOVE WOLVERINE CREEK (09EC001)

Graph: 09EC001 Daily Refresh



Statistics corresponding to 2 years of data recorded from January 1964 to December 1965.*[*]*

Station Information: CLINTON CREEK ABOVE WOLVERINE CREEK (09EC001)

Active or discontinued	Discontinued	**Province/Territory**	Yukon
Latitude	64°26'54" N	**Longitude**	140°42'24" W
Gross drainage area			
Record length	2 years	**Period of record**	1964 - 1965
Regulation type	Natural		

Period of record	Hydrometric measurement type	Operational schedule	Gauge type
1964 - 1965	Flow	Seasonal	Manual
1966 - 1966	Level	Seasonal	Manual

FORTYMILE RIVER NEAR THE MOUTH (09EC002)

Statistics corresponding to 15 years of data recorded from January 1982 to December 1996.**

Station Information: FORTYMILE RIVER NEAR THE MOUTH (09EC002)

Active or discontinued	Discontinued	**Province/Territory**	Yukon
Latitude	64°23'50" N	**Longitude**	140°36'40" W
Gross drainage area	16600 km^2		
Record length	15 years	**Period of record**	1982 – 1996
Regulation type	Natural		

Period of record	Hydrometric measurement type	Operational schedule	Gauge type
1981 - 1981	Flow	Miscellaneous	Recorder
1982 - 1982	Flow	Seasonal	Recorder
1983 - 1998	Flow	Continuous	Recorder