Tailings Risk Assessment
Minto Project, Yukon Territory

Prepared for

Minto Explorations Ltd.

Prepared by

SRK Consulting
Engineers and Scientists

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Tailings Risk Assessment

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Table of Contents

List of Tables

List of Figures

List of Appendices

1 Introduction

The Yukon Government, Department of Energy, Mines and Resources (EMR), as part of special conditions imposed on two certificates of approval related to the Minto Mine tailings facility in the central Yukon (Figure 1), requires that Minto Explorations Ltd. (Minto) complete a risk assessment for the tailings facility. The original notification stipulated a deadline of December 31, 2008 for the submission of this risk assessment. However in late December, 2008, Minto was granted an extension to February 15, 2009.

In response to the EMR requirement, Minto entered into a contract with SRK Consulting (Canada) Inc. (SRK) in December 2008 to complete the risk assessment. SRK has completed the risk assessment for the Minto tailings facility using a Failure Modes and Effects Analysis (FMEA). Haimes (2004)[1] describes an FMEA as a risk-based method that is "widely used for reliability analysis of systems, subsystems, and individual component of systems. It constitutes an enabling mechanism with which to identify the multiple paths of system failures. Indeed, a requisite for an effective risk assessment process is to identify all conceivable failure modes of a system."

It is assumed that the reader is familiar with FMEA's and, therefore, only brief detailed explanations of the process are provided within this report. For additional information regarding FMEA's and their use, the reader is directed to Appendix A.

Normally, the execution of an FMEA is characterized by the participation of both designers and operators of the system, facilitation by an independent expert, and the use of a structured process designed to ensure that all modes of failure are identified and fairly assessed. However, given the relative simplicity of the Minto tailings facility, the FMEA has been completed using a small team of specialists from SRK and a review by staff from Minto and EBA Engineering Consultants Ltd. (EBA), the firm that designed the tailings facility. In particular, the FMEA text and summary table were developed by the author, Cam Scott, P. Eng. with input from Terry Mandziak, P.E. A technical review was undertaken by Dr. Dirk van Zyl, an associate of SRK with extensive experience in FMEA assessments for mine facilities. Additional review was provided by Minto personnel familiar with the design, construction and operation of the tailings facility.

This report describes the approach taken to complete the FMEA (Section 4) and the results (Section 5). Based on the outcome of the FMEA process, a series of conclusions are provided (Section 6).

[1] Haimes, Y.Y. (2004) Risk Modeling, Assessment, and Management, 2nd Edition, John Wiley and Sons, 837 pp.

2 Objective

EMR requested the risk assessment address the following:

- Failure modes under both operational conditions and post-closure;
- Likelihood of failure;
- A method of identifying which are the most significant risks; and
- The adequacy of the adaptive management plan for the tailings.

As noted above, an FMEA is an effective tool for identifying the possible risks associated with potential failure modes of complex engineered systems, and for determining which risks are the most significant. The outcome of an FMEA should be considered to be a “screening” of risks that can be set aside as being sufficiently low as to not warrant further investigation and assessment, and the generation of a priority list of those issues for which the risk is considered sufficient to justify more investigation and mitigation, where necessary. It is therefore a basis for prioritizing evaluation of remaining risks which may be unacceptably high, with the objective of reducing risk to acceptable levels.

3 The Boundaries of the Risk Assessment

The Minto tailings facility FMEA focused on the dry stack tailings facility and its immediate surroundings. In particular, the FMEA has included the following elements:

- Dry stack and the area within its catchment;
- Water management within this area; and
- Site management and regulatory oversight issues.

A plan view of the tailings facility is provided in Figure 2. Typical sections through the tailings facility are provided in Figure 3. Note that the FMEA does not include the water supply dam as it is not directly linked to the routine disposal of tailings at the Minto Mine.

Failure modes were developed and described for two project stages:

- operations (OP), including current operations through to the end of the mine’s operating life; and
- post closure (PC).

Further information on each of these project stages is provided in the following table.

Stage	Characteristics	Comments
Operations, OP	Current maximum tailings thickness: 8m Maximum design thickness at closure: 23m	Refers to the operating period that extends from today, through till the plant shuts down at the end of the operating life (in approx. 6 yrs although mine life is expected to increase based on exploration drilling results).
Post closure, PC	Maximum tailings elev. at closure: 792m Lowest elev. in the tailings deposition area: 760m	Refers to the 100-year period following the implementation of the closure plan.

4 FMEA Methodology

A large number of failure modes have been described and analyzed in relation to their potential effects. In most cases, both project stages (OP and PC) have required consideration as part of the various failure modes.

The following broad categories have been used to develop the detailed failure modes:

1. Deep-seated failure (within the foundation, above and/or below the permafrost) under static or dynamic loading conditions;
2. Failure of the stack (above the foundation) under static or dynamic loading conditions;
3. Failure of the exposed tailings face under static or dynamic loading conditions before waste rock has been placed over the face;
4. Creep due to the presence of ice within the foundation;
5. Plugging of the drainage systems;
6. Seepage of non-compliant quality; and
7. Site management and regulatory oversight issues.

The effects associated with the first three categories listed above are repeated a number of times according to three distinctly different scenarios. Two of these scenarios are linked to the operational life of the mine and the third is linked to the post-closure period, by which time the water dam located approximately 1 km downstream of the low point in the tailings facility will have been removed. For reference, the distance between the tailings facility and the floodplain of the Yukon River it is about 8 km. It is an additional 0.5 km from the edge of the floodplain to the confluence of Minto Creek with the Yukon River.

Effects scenario #1:

During operations, tailings stay within Upper Minto Creek drainage area, i.e. they collect in the water dam reservoir as part of the initial failure or post-failure transport by water. There is no discharge of non-compliant water or tailings solids over the spillway.

Effects scenario #2:

During operations, tailings collect behind the water dam but, due to displacement of the water within the reservoir, non-compliant water and some colloidal tailings solids flow over the spillway.

Effects scenario #3:

Post closure, tailings enter Upper Minto Creek as part of the initial failure or post-failure transport by water. The sandy fraction of the tailings solids settle within a few kilometres or less of the tailings facility, but some of the fine tailings solids (the silt and clay fraction) are carried by creek flow into the Yukon River.

In the case of the next two categories (creep and plugging of the drainage systems), it has been assumed that remedial measures will be implemented before the tailings can reach Lower Minto Creek. The effects associated with these two categories are therefore less than has been assumed for the three preceding failure categories.

The last failure category (site management and regulatory events) is provided for consideration, but since the effects are likely to vary depending on external factors and the effectiveness of the ongoing programs and their implementation, no assignation of the likelihood and consequences has been provided.

The likelihood of the occurrence of each failure event, ranging from 'not likely' (NL) to 'expected' (E), has been assessed on the basis of the probabilities as shown in Table 1. The severity of the effects associated with each failure mode has been assessed according to the following five categories:

- Direct cost;
- Environmental impact;
- Regulatory and legal impacts;
- Public concern and reputation; and
- Public safety.

Within each of these five categories, the severity of the effects associated with each failure mode, ranging from 'negligible' (N) to 'extreme' (E), have been defined on the basis of the descriptions provided in Table 2. The severity of effects of failures related to site management and regulatory oversight issues have not been defined given the potential variability in their effects.

The confidence level associated with each failure mode and its respective assessment, ranging from 'low" (L) to 'high' (H), has been defined on the basis of the classifications provided in Table 3.

Table 4 provides the complete assessment for each failure mode, including comments and possible mitigation measures that would reduce the risk of the respective failure mode.

5 FMEA Results

As noted above, Table 4 summarizes the list of failure modes, assessed likelihoods, severity of consequences and, for some failure modes, comments and possible mitigation measures. The cells in Table 4 describing the consequences are shaded using the colors in the attached Risk Tables (Tables 5.1 through 5.5). Risk is the product of multiplying the likelihood of failure by the severity of the consequences. Each Risk Table corresponds to a particular consequence category, i.e. direct cost, environmental impact, regulatory and legal, public concern & reputation and public safety, respectively. The colors in each table indicate the various risks posed by a combination of the likelihood of a failure mode occurring and the consequences of the failure mode if it should occur. The orange to red colors indicate high risk failure modes while the blue colors indicate low to very low risk failure modes. Green indicates the failure mode has a moderate risk.

The information provided in the five Risk Tables can be summarized as follows:

- The highest risk identified by this assessment is that, post closure, seepage which discharges from the tailings facility may not meet discharge quality. Although the quantity of this flow is expected to be small, the discharge of non-compliant water could lead to significant impacts relative to regulatory requirements, public perception and, ultimately, remediation costs.
- In general, most failure modes involve physical stability and the main impacts are linked to one or both of regulatory/legal issues or public concern/reputation issues. Specific to these issues, these failure modes are categorized as low to moderate risk. While there would be cost issues associated with these failure modes, these are expected to be relatively modest and are therefore typically categorized as low risk.
- The risks associated with environmental impacts are relatively low because:
  - the condition of the stored tailings practically eliminates the likelihood of large scale flow failures, and
  - the geochemical characteristics of the tailings are generally favourable.
- There are no significant risks to public safety.

The fact that the physical stability failure modes are typically low to moderate risk is to be expected given the differences between a tailings storage facility constructed for dewatered tailings and, for example, a conventional tailings impoundment that involves storage of slurried tailings and a supernatant pond.

6 Conclusions

Based on the results of the risk assessment, conclusions related to the mitigation of risks associated with the Minto tailings facility are provided below.

The regulatory requirements appropriate to mitigate the risks identified in the FMEA are in place. Mechanisms for reporting the data collected related to the performance of the tailings facility are built into existing licences and permits, many of them subject to in-depth stakeholder review prior to approval. These include:

- a tailings operations, maintenance and surveillance (OMS) manual which guides the monitoring and oversight of the tailings facility by Minto Mine staff;
- a physical monitoring program, as referenced in section 9.3.1 of the Quartz Mining Licence QML-0001 and described in Water Use Licence QZ96-006 (Appendix 2), which is summarized in annual reports related to both licences;
- an adaptive management model (part of the tailings management plan) that provides monitoring and surveillance staff at Minto Mine with specific triggers or thresholds and follow up actions that are required should field conditions change unexpectedly;
- annual reporting by a professional engineer on the condition of the dry stack tailings foundation and slopes based on field inspections and the results of the surveillance and monitoring program; and
- revised interim closure plans which are required every second year as per the Quartz Mining Licence QML-0001, section 14.3. As indicated in section 5.9 of the approved Detailed Decommissioning and Reclamation Plan (2007), each revision as it pertains to the tailings facility, will account for the monitoring and surveillance program results and the adaptive management model.

As described in the OMS manual, the existing monitoring program includes in situ instrumentation (i.e. piezometers, thermistors), compaction testing, regular inspections and ongoing technical advice from the engineer of record. Therefore, an appropriate program of monitoring is in place, and amendments are planned when and where appropriate. The next amendment should include contingency plans which address potential failure modes related to thawing permafrost within the foundation of the tailings facility.

Further assessment of the geochemical properties of the stored tailings, with a view to refining predictions regarding the quality of toe seepage from the tailings facility post closure, would be appropriate based on this FMEA.

This report, "**Tailings Risk Assessment, Minto Project, Yukon Territory**," was prepared by SRK Consulting (Canada) Inc.

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Tables

Table 1: Likelihood of Event

Likelihood	As a Percentage	As a Statistical Number
Not Likely (NL)	<0.01%	<1:10,000
Low (L)	0.01 – 0.1%	1:10,000 to 1:1,000
Moderate (M)	0.1 - 1%	1:1,000 to 1:100
High (H)	1 - 10%	1:100 to 1:10
Expected (E)	>10%	>1:10

Table 2: Severity of Effects

Severity	Direct Cost	Environmental Impact	Regulatory and Legal Impacts	Public Concern and Reputation	Public Safety
Extreme (E)	>$10 M	Catastrophic impact on habitat (irreversible and large)	Unable to meet regulatory obligations or expectations; shut down or severe restriction of operations	Local, international and NGO outcry and demonstrations, results in large stock devaluation: severe restrictions of 'license to practice'; large compensatory payments etc.	Fatality or multiple fatalities expected
High (H)	$1M - $10 M	Significant, irreversible impact on habitat or large, reversible	Regularly (more than once per year) or severely fail regulatory obligations or expectations - large increasing fines and loss of regulatory trust	Local, international or NGO activism resulting in political and financial impacts on company 'license to do business' and in major procedure or practice changes,	Severe injury or disability likely: or some potential for fatality
Moderate (M)	$100K - $1 M	Significant, reversible impact on habitat	Occasionally (less than one per year) or moderately fail regulatory obligations or expectations - fined or censured	Occasional local, international and NGO attention requiring minor procedure changes and additional public relations and communications	Lost time or injury likely: or some potential for serious injuries; or small risk of fatality.
Low (L)	$10K - $100K	Minor impact on habitat	Seldom or marginally exceed regulatory obligations or expectations. Some loss of regulatory tolerance, increasing reporting.	Infrequent local, international and NGO attention addressed by normal public relations and communications	First aid required; or small risk of serious injury.
Negligible (N)	<$10K	No measurable impact	Do not exceed regulatory obligations or expectations	No local/international/ NGO attention	No concern

K = thousand; M = million

Table 3: FMEA – Level of Confidence

Confidence Level	Description
Low (L)	Do not have confidence in the estimate or ability to control during operations, or post-closure.
Medium (M)	Have some confidence in the estimate or ability to control during operations, or post-closure; conceptual level analyses.
High (H)	Have lots of confidence in the estimate or ability to control during operations, or post-closure; detailed analyses following a high standard of care.

Table 4: Failure Modes and Effects Analysis (FMEA) Worksheet – Minto "Dry Stack" Tailings Storage Facility

ID	FAILURE MODE	EFFECTS	PROJECT STAGE	LIKELIHOOD	SEVERITY OF EFFECTS: DIRECT COST	ENVIRONMENTAL IMPACT	REGULATORY & LEGAL	PUBLIC CONCERN & REPUTATION	PUBLIC SAFETY	LEVEL OF CONFIDENCE	MITIGATION / COMMENTS
1	**Deep-seated stack failure under static loading conditions**										
1.1	- Non-circular failure from the crest of the stack, through either the organic soils at the original ground surface or the thawing of ice-rich soils at the top of the permafrost; caused by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses.	Displacements are large enough to move tailings very close to, or into, Minto Creek, which leads to some tailings washing downstream and collecting in the pond behind the water dam.	OP	L	M	N	H	H	L	L	Ongoing monitoring (including in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record) per OMS manual and regulatory requirements should mitigate risks appropriately. Regular updating of OMS and Management Plan to include contingency plans. EBA's 07/08 annual review (July 08) reports that data/observations for that period showed no concerns related to thaw stability.
1.2	- Non-circular failure from the crest of the stack, through either the organic soils at the original ground surface or the thawing of ice-rich soils at the top of the permafrost; caused by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses.	Displacements are such that, through either (i) blockage of Minto Creek and the subsequent erosion of tailings or (ii) movement of tailings during the failure, tailings enter the pond behind the water dam and cause an uncontrolled discharge of non-compliant water and colloidal tailings solids over the spillway.	OP	NL	H	H	E	H	L	L	Ongoing monitoring (including in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record) per OMS manual and regulatory requirements should mitigate risks appropriately. Regular updating of OMS and Management Plan to include contingency plans. EBA's 07/08 annual review (July 08) reports that data/observations for that period showed no concerns related to thaw stability.
1.3	- Non-circular failure from the crest of the stack, through either the organic soils at the original ground surface or the thawing of ice-rich soils at the top of the permafrost; caused by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses.	Displacements are large enough to move tailings very close to or into Minto Creek, which leads to tailings being washed downstream, including clay and some silt-sized tailings solids which reach the Yukon River.	PC	L	M	H	H	H	N	L	Mitigate the risk of this failure mode by implementing appropriate closure measures and a post-closure monitoring plan for an appropriate period. Regular updating of OMS and Management Plan to include contingency plans.
1.4	- Non-circular failure from the crest of the stack, through weak soils <u>beneath the permafrost</u>; caused by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses.	Displacements are large enough to move tailings very close to, or into, Minto Creek, which leads to some tailings washing downstream and collecting in the pond behind the water dam.	OP	NL	M	N	H	H	L	L	Continue to monitor the site specific foundation conditions and related geotechnical properties. Current monitoring includes in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record. Regular updating of OMS and Management Plan to include contingency plans.
1.5	- Non-circular failure from the crest of the stack, through weak soils <u>beneath the permafrost</u>; caused by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses.	Displacements are such that, through either (i) blockage of Minto Creek and the subsequent erosion of tailings or (ii) movement of tailings during the failure, tailings enter the pond behind the water dam and cause an uncontrolled discharge of non-compliant water and colloidal tailings solids over the spillway.	OP	NL	H	H	E	H	L	L	Continue to monitor the site specific foundation conditions and related geotechnical properties. Current monitoring includes in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record. Regular updating of OMS and Management Plan to include contingency plans.
1.6	- Non-circular failure from the crest of the stack, through weak soils <u>beneath the permafrost</u>; caused by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses.	Displacements are large enough to move tailings very close to or into Minto Creek, which leads to tailings being washed downstream, including clay and some silt-sized tailings solids which reach the Yukon River.	PC	NL	M	H	H	H	N	L	Mitigate the risk of this failure mode by implementing appropriate closure measures and a post-closure monitoring plan for an appropriate period. Regular updating of OMS and Management Plan to include contingency plans.
2	**Deep-seated stack failure under dynamic loading conditions**										
2.1	- Non-circular failure from the crest of the stack, through either the organic soils at the original ground surface or the thawing of ice-rich soils at the top of the permafrost; triggered by the design earthquake but exacerbated by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses; (iii) poor estimate of the design earthquake; or (iv) earthquake exceeds the design earthquake.	Displacements are large enough to move tailings very close to, or into, Minto Creek, which leads to some tailings washing downstream and collecting in the pond behind the water dam.	OP	L	M	N	H	H	L	L	Ongoing monitoring (including in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record) per OMS manual and regulatory requirements should mitigate risks appropriately. Regular updating of OMS and Management Plan to include contingency plans.

2.2	- Non-circular failure from the crest of the stack, through either the organic soils at the original ground surface or the thawing of ice-rich soils at the top of the permafrost; triggered by the design earthquake but exacerbated by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses; (iii) poor estimate of the design earthquake; or (iv) earthquake exceeds the design earthquake.	Displacements are such that, through either (i) blockage of Minto Creek and the subsequent erosion of tailings or (ii) movement of tailings during the failure, tailings enter the pond behind the water dam and cause an uncontrolled discharge of non-compliant water and colloidal tailings solids over the spillway.	OP	NL	**H**	**H**	**E**	**H**	**L**	**L**	Ongoing monitoring (including in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record) per OMS manual and regulatory requirements should mitigate risks appropriately. Regular updating of OMS and Management Plan to include contingency plans.
2.3	- Non-circular failure from the crest of the stack, through either the organic soils at the original ground surface or the thawing of ice-rich soils at the top of the permafrost; triggered by the design earthquake but exacerbated by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses; (iii) poor estimate of the design earthquake; or (iv) earthquake exceeds the design earthquake.	Displacements are large enough to move tailings very close to or into Minto Creek, which leads to tailings being washed downstream, including clay and some silt-sized tailings solids which reach the Yukon River.	PC	L	**M**	**H**	**H**	**H**	**N**	**L**	Mitigate the risk of this failure mode by implementing appropriate closure measures and a post-closure monitoring plan for an appropriate period. Regular updating of OMS and Management Plan to include contingency plans.
2.4	- Non-circular failure from the crest of the stack, through weak soils <u>beneath the permafrost</u>; triggered by the design earthquake but exacerbated by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses; (iii) poor estimate of the design earthquake; or (iv) earthquake exceeds the design earthquake.	Displacements are large enough to move tailings very close to, or into, Minto Creek, which leads to some tailings washing downstream and collecting in the pond behind the water dam.	OP	NL	**M**	**N**	**H**	**H**	**L**	**L**	Ongoing monitoring (including in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record) per OMS manual and regulatory requirements should mitigate risks appropriately. Regular updating of OMS and Management Plan to include contingency plans.
2.5	- Non-circular failure from the crest of the stack, through weak soils <u>beneath the permafrost</u>; triggered by the design earthquake but exacerbated by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses; (iii) poor estimate of the design earthquake; or (iv) earthquake exceeds the design earthquake.	Displacements are such that, through either (i) blockage of Minto Creek and the subsequent erosion of tailings or (ii) movement of tailings during the failure, tailings enter the pond behind the water dam and cause an uncontrolled discharge of non-compliant water and colloidal tailings solids over the spillway.	OP	NL	**H**	**H**	**E**	**H**	**L**	**L**	Ongoing monitoring (including in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record) per OMS manual and regulatory requirements should mitigate risks appropriately. Regular updating of OMS and Management Plan to include contingency plans.
2.6	- Non-circular failure from the crest of the stack, through weak soils <u>beneath the permafrost</u>; triggered by the design earthquake but exacerbated by one or more of the following: (i) elevated phreatic levels in the stacked tailings and/or foundation; (ii) inaccurate shear strength properties used in the stability analyses; (iii) poor estimate of the design earthquake; or (iv) earthquake exceeds the design earthquake.	Displacements are large enough to move tailings very close to or into Minto Creek, which leads to tailings being washed downstream, including clay and some silt-sized tailings solids which reach the Yukon River.	PC	NL	**M**	**H**	**H**	**H**	**N**	**L**	Mitigate the risk of this failure mode by implementing appropriate closure measures and a post-closure monitoring plan for an appropriate period. Regular updating of OMS and Management Plan to include contingency plans.
3	**Stack failure under static loading conditions (foundation not affected)**										
3.1	- Slumping or toe failure due to one or more of the following: (i) elevated phreatic levels in the stacked tailings; (ii) inaccurate shear strength properties used in the stability analyses.	Displacements are large enough to move tailings very close to, or into, Lower Minto Creek, which leads to some tailings washing downstream and collecting in the pond behind the water dam.	OP	L	**M**	**N**	**H**	**M**	**L**	**M**	Ongoing monitoring (including in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record) per OMS manual and regulatory requirements should mitigate risks appropriately.
3.2	- Slumping or toe failure due to one or more of the following: (i) elevated phreatic levels in the stacked tailings; (ii) inaccurate shear strength properties used in the stability analyses.	Displacements are such that, through either (i) blockage of Minto Creek and the subsequent erosion of tailings or (ii) movement of tailings during the failure, tailings enter the pond behind the water dam and cause an uncontrolled discharge of non-compliant water and colloidal tailings solids over the spillway.	OP	NL	**H**	**H**	**E**	**H**	**L**	**M**	Ongoing monitoring (including in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record) per OMS manual and regulatory requirements should mitigate risks appropriately.
3.3	- Slumping or toe failure due to one or more of the following: (i) elevated phreatic levels in the stacked tailings; (ii) inaccurate shear strength properties used in the stability analyses.	Displacements are large enough to move tailings very close to or into Minto Creek, which leads to tailings being washed downstream, including clay and some silt-sized tailings solids which reach the Yukon River.	PC	L	**M**	**H**	**H**	**M**	**N**	**M**	Mitigate the risk of this failure mode by implementing appropriate closure measures and a post-closure monitoring plan for an appropriate period.
4	**Stack failure under dynamic loading conditions (foundation not affected)**										
4.1	- Slumping or toe failure due to seismically triggered loss of strength within those portions of the stack (i) for which the tailings are unfrozen and (ii) which do not meet the design density criterion.	Displacements are large enough to move tailings very close to, or into, Lower Minto Creek, which leads to some tailings washing downstream and collecting in the pond behind the water dam.	OP	L	**M**	**N**	**H**	**M**	**L**	**M**	Ongoing monitoring (including in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record) per OMS manual and regulatory requirements should mitigate risks appropriately.

4.2	- Slumping or toe failure due to seismically triggered loss of strength within those portions of the stack (i) for which the tailings are unfrozen and (ii) which do not meet the design density criterion.	Displacements are such that, through either (i) blockage of Minto Creek and the subsequent erosion of tailings or (ii) movement of tailings during the failure, tailings enter the pond behind the water dam and cause an uncontrolled discharge of non-compliant water and colloidal tailings solids over the spillway.	OP	NL	H	H	E	H	L	M	Ongoing monitoring (including in situ instrumentation, compaction testing, regular inspections and ongoing technical advice from engineer of record) per OMS manual and regulatory requirements should mitigate risks appropriately.
4.3	- Slumping or toe failure due to seismically triggered loss of strength within those portions of the stack (i) for which the tailings unfrozen and (ii) which do not meet the design density criterion.	Displacements are large enough to move tailings very close to or into Minto Creek, which leads to tailings being washed downstream, including clay and some silt-sized tailings solids which reach the Yukon River.	PC	L	M	H	H	M	N	M	Mitigate the risk of this failure mode by implementing appropriate closure measures and a post-closure monitoring plan for an appropriate period.
5	**Failure of exposed tailings face under static loading conditions**										
5.1	- Slumping of exposed face due to thawing of the exposed face; likely to occur in the spring or early summer as infiltration to the surface of the tailings leads to a buildup in pore pressures.	Tailings slump onto the waste rock shell downslope of the tailings face and small quantities of tailings wash into Minto Creek and collect in the pond behind the water dam.	OP	L	L	N	M	L	L	H	Operator to be diligent about installing the waste rock shell adjacent to the tailings face in a timely manner. Construction of diversion berms and proper grading should occur as per the design.
5.2	- Gully erosion on the face due to surface runoff; likely to occur at any time in the year when the face is not frozen.	Eroded tailings wash into Minto Creek and collect in the pond behind the water dam.	OP	M	L	N	M	L	L	H	Operator to be diligent about installing the waste rock shell adjacent to the tailings face in a timely manner. Construction of diversion berms and proper grading should occur as per the design.
6	**Failure of exposed tailings face under dynamic loading conditions**										
6.1	- Slumping of exposed face during an earthquake	Tailings slump onto the waste rock shell downslope of the tailings face and small quantities of tailings wash into Minto Creek and collect in the pond behind the water dam.	OP	L	L	N	M	L	L	H	Operator to be diligent about installing the waste rock shell adjacent to the tailings face in a timely manner. Construction of diversion berms and proper grading should occur as per the design.
7	**Creep displacement deep within the permafrost due to:**										
7.1	- An unfavorable amount and distribution of ground ice in the formation.	Gradual deformation of the tailings stack, which impacts the drainage systems and leads to the migration of tailings through the waste rock shell.	OP	NL	M	N	L	N	N	L	Monitor during operations. If indications of creep displacement are detected/suspected, verification of known permafrost conditions may be required. Develop and cost a contingency plan as part of closure.
7.2	- An unfavorable amount and distribution of ground ice in the formation.	Gradual deformation of the tailings stack, which impacts the drainage systems and leads to the migration of tailings through the waste rock shell.	PC	L	M	N	L	N	N	L	Monitor during operations and closure. If indications of creep displacement are detected/suspected, verification of known permafrost conditions may be required. Develop and cost a contingency plan as part of closure.
7.3	- An unfavorable amount and distribution of ground ice in the formation.	Gradual deformation of the tailings stack which leads to some tailings being washed downstream, including a small percentage of the very fine tailings which reach the Yukon River.	PC	NL	M	L	L	M	N	L	Monitor during operations and closure. If indications of creep displacement are detected/suspected, verification of known permafrost conditions may be required. Develop and cost a contingency plan as part of closure.
8	**Plugging of one or more finger drains due to:**										
8.1	- Degradation of the rock fill due to physical and chemical weathering.	Leads to elevated flow rate that exceeds the capacity of the drainage systems (finger and/or blanket), leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	OP/PC	L	L	N	L	L	N	L	Monitor rock fill as per operations manual during operations stage. If rock fill shows signs of weathering, additional data regarding the physical and chemical weathering characteristics of the rock fill may be required and corrective measures would then be determined. Use monitoring results in developing appropriate closure methods and post-closure monitoring.
8.2	- Formation of precipitates.	Leads to elevated flow rate that exceeds the capacity of the drainage systems (finger and/or blanket), leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	OP/PC	NL	L	N	L	L	N	L	Existing data suggests there is a very low likelihood of precipitates forming and blocking the drain. Continue to monitor the drain performance.
8.3	- Migration of soil particles into the drain from upstream of tailings footprint, or the migration of tailings into the drain due to inadequate filtration.	Leads to elevated flow rate that exceeds the capacity of the drainage systems (finger and/or blanket), leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	OP/PC	L	L	N	L	L	N	L	The extent to which particle migration occurs will depend on the quality and construction details associated with the filter materials/zones, therefore diligence required in adhering to construction specifications of finger drain materials. Monitoring of drains for proper functioning is ongoing. Use monitoring results in developing appropriate closure methods and post-closure monitoring program.
9	**Plugging of underdrain as a result of:**										
9.1	- Degradation of the rock fill due to physical and chemical weathering.	Leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	PC	L	L	N	L	L	N	L	Monitor rock fill per the OMS manual during operations stage. If rock fill shows signs of weathering, additional data regarding the physical and chemical weathering characteristics of the rock fill may be warranted and corrective measures would then be determined. Use monitoring results in developing appropriate closure methods and post-closure monitoring.

9.2	- Formation of precipitates.	Leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	PC	NL	L	N	L	L	N	L	Existing data suggests there is a very low likelihood of precipitates forming and blocking the drain. Continue to monitor the drain performance.
9.3	- Migration of tailings into the drain due to inadequate filtration.	Leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	PC	L	L	N	L	L	N	L	The extent to which particle migration occurs will depend on the quality and construction details associated with the filter materials/zones, therefore diligence required in adhering to construction specifications of underdrain materials. Monitoring of already-constructed underdrains for proper functioning is ongoing. Use monitoring results in developing appropriate closure methods and post-closure monitoring program.
10	**Breaching of the diversion ditch system as a result of:**										
10.1	- Thawing of permafrost that leads to deformations and/or settlement of the water management structure.	Leads to elevated flow rate onto TSF that exceeds the capacity of the drainage systems (finger and/or blanket), leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	OP	NL	N	N	L	L	N	L	Regular monitoring should identify potential problems during operations. Remediation should be very easy to achieve.
10.2	- Thawing of permafrost that leads to deformations and/or settlement of the water management structure.	Leads to elevated flow rate onto TSF that exceeds the capacity of the drainage systems (finger and/or blanket), leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	PC	L	L	N	L	L	N	L	Periodic monitoring post-closure should identify potential problems. Remediation could be done on a periodic basis assuming most of the problems occur within a few years post closure.
10.3	- Erosion and breaching of the water management structure during an extreme flood event.	Leads to elevated flow rate onto TSF that exceeds the capacity of the drainage systems (finger and/or blanket), leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	OP	NL	N	N	L	L	N	L	Regular monitoring should identify potential problems during operations. Remediation should be very easy to achieve.
10.4	- Erosion and breaching of the water management structure during an extreme flood event.	Leads to elevated flow rate onto TSF that exceeds the capacity of the drainage systems (finger and/or blanket), leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	PC	L	L	N	L	L	N	L	Periodic monitoring post-closure should identify potential problems. Remediation could be done on a periodic basis assuming most of the problems occur within a few years post closure.

10.5	- Breaching of the water management structure during freshet due to glaciation over the past winter.	Leads to elevated flow rate onto TSF that exceeds the capacity of the drainage systems (finger and/or blanket), leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	OP	NL	N	N	L	L	N	L	Regular monitoring should identify potential problems during operations. Remediation should be very easy to achieve.
10.6	- Breaching of the water management structure during freshet due to glaciation over the past winter.	Leads to elevated flow rate onto TSF that exceeds the capacity of the drainage systems (finger and/or blanket), leads to elevated pore pressures followed by localized slope failure within the waste rock shell.	PC	L	L	N	L	L	N	L	Periodic monitoring post-closure should identify potential problems. Remediation could be done on a periodic basis assuming most of the problems occur within a few years post closure.
11	**Quality of water seeping through the tailings stack exceeds allowable discharge criteria.**										
11.1	- Non-compliant water is discharged from the drainage systems because (i) significant portions of the tailings are unfrozen and (ii) leaching of residual metals within the tailings in a non-acidic environment is occurring.	Seepage reports to the water dam, affecting the water quality of the pond and leading to modifications of the current water treatment system.	OP	M	M	N	L	N	N	L	Ongoing sampling and monitoring will indicate whether this failure mode is starting to occur.
11.2	- Non-compliant water is discharged from the drainage systems because of one or more of the following: (i) imperfections exist in the liner/cover, (ii) significant portions of the tailings are unfrozen and (iii) leaching of residual metals within the tailings in a non-acidic environment is occurring.	Water which discharges from the toe of the TSF flows into Minto Creek and then into the Yukon River.	PC	H	M	L	H	M	N	L	As closure approaches, it will be possible to obtain a better prediction of whether this failure mode is realistic. At that time, contingency measures such as limestone drains and/or wetland treatment systems in conjunction with or instead of traditional treatment, could be explored, if appropriate.
12	**Oversight or management failure**	Variable	OP/PC								Operation and maintenance manuals set out specific requirements and responsibilities during operations. Closure plan will set out specific requirements and responsibilities post-closure.
13	**Failure of regulatory oversight**	Variable	OP/PC								The closure plan should identify a site management plan that involves Minto, the Yukon regulatory agencies, and First Nation stakeholders, to ensure that, if there is a breakdown in any one link, there is still oversight throughout the required post-closure period.
14	**Willful damage (vandalism, terrorism, etc.)**	Variable	OP/PC								Can be mitigated by proper site management protocols that may be modified on the basis of perceived likelihood of occurrence.

Table 5.1: Risk Matrix for Direct Cost Effects

		LIKELIHOOD				
		NOT LIKELY	LOW	MODERATE	HIGH	EXPECTED
SEVERITY OF EFFECTS	EXTREME					
	HIGH	1.2, 1.5, 2.2, 2.5, 3.2, 4.2				
	MODERATE	1.4, 1.6, 2.4, 2.6, 7.1, 7.3	1.1, 1.3, 2.1, 2.3, 3.1, 3.3, 4.1, 4.3, 7.2	11.1	11.2	
	LOW	8.2, 9.2	5.1, 6.1, 8.1, 8.3, 9.1, 9.3, 10.2, 10.4, 10.6	5.2		
	NEGLIGIBLE	10.1, 10.3, 10.5				

Table 5.2: Risk Matrix for Environmental Effects

		LIKELIHOOD				
		NOT LIKELY	LOW	MODERATE	HIGH	EXPECTED
SEVERITY OF EFFECTS	EXTREME					
	HIGH	1.2, 1.5, 1.6, 2.2, 2.5, 2.6, 3.2, 4.2	1.3, 2.3, 3.3, 4.3			
	MODERATE					
	LOW	7.3	9.1		11.2	
	NEGLIGIBLE	1.4, 2.4, 7.1, 8.2, 9.2, 10.1, 10.3, 10.5	1.1, 2.1, 3.1, 4.1, 5.1, 6.1, 7.2, 8.1, 8.3, 9.3, 10.2, 10.4, 10.6	5.2, 11.1		

Table 5.3: Risk Matrix for Regulatory and Legal Effects

		LIKELIHOOD				
		NOT LIKELY	LOW	MODERATE	HIGH	EXPECTED
SEVERITY OF EFFECTS	EXTREME	1.2, 1.5, 2.2, 2.5, 3.2, 4.2				
	HIGH	1.4, 1.6, 2.4, 2.6	1.1, 1.3, 2.1, 2.3, 3.1, 3.3, 4.1, 4.3		11.2	
	MODERATE		5.1, 6.1	5.2		
	LOW	7.1, 7.3, 8.2, 9.2, 10.1, 10.3, 10.5	7.2, 8.1, 8.3, 9.1, 9.3, 10.2, 10.4, 10.6	11.1		
	NEGLIGIBLE					

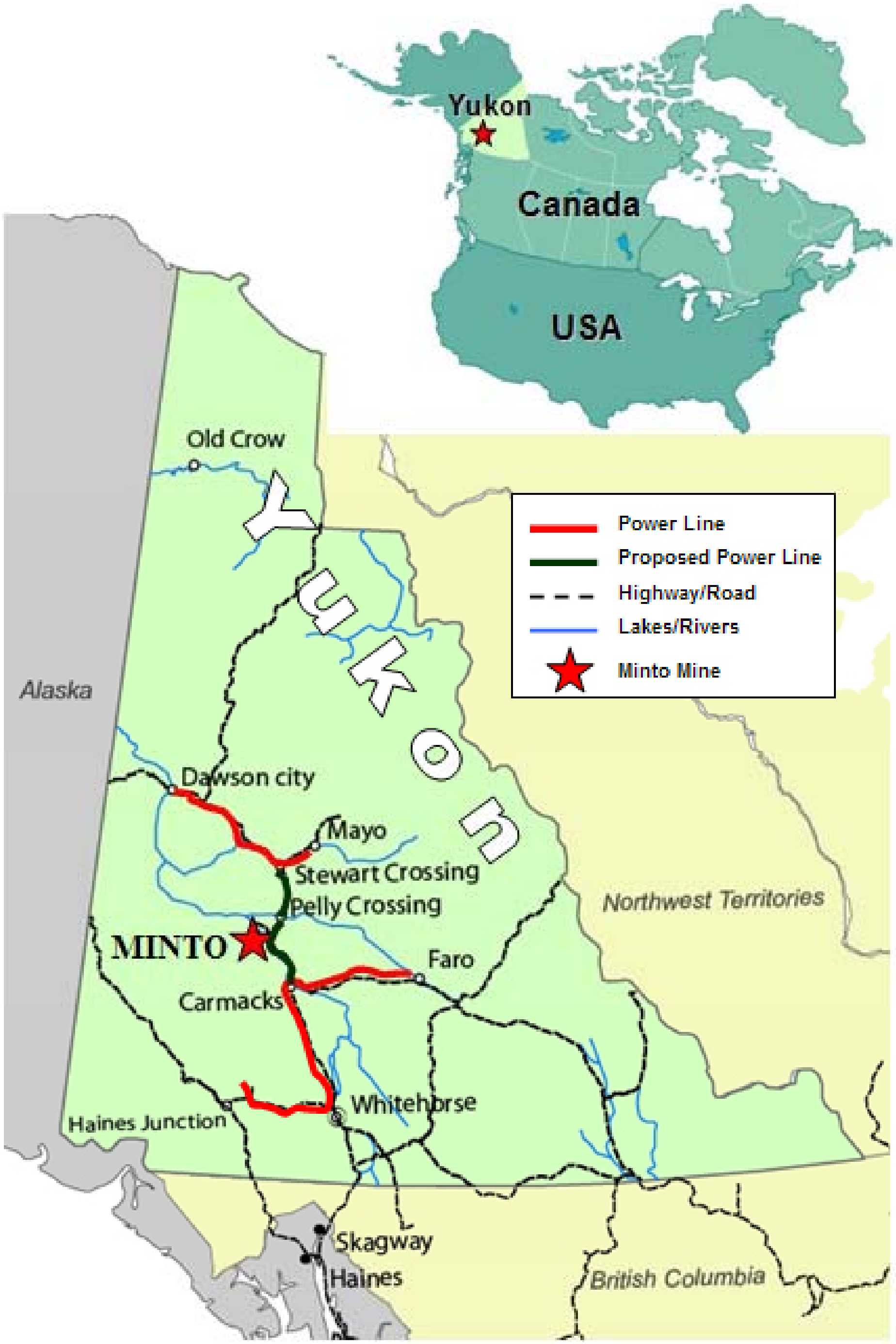
Table 5.4: Risk Matrix for Public Concern and Reputation Effects

		LIKELIHOOD				
		NOT LIKELY	LOW	MODERATE	HIGH	EXPECTED
SEVERITY OF EFFECTS	EXTREME					
	HIGH	1.2, 1.5, 2.2, 2.4, 2.5, 2.6, 3.2, 4.2	1.1, 1.3, 2.1, 2.3			
	MODERATE	7.3	1.4, 1.6, 3.1, 3.3, 4.1, 4.3		11.2	
	LOW	8.2, 9.2, 10.1, 10.3, 10.5	5.1, 6.1, 8.1, 8.3, 9.1, 9.3, 10.2, 10.4, 10.6	5.2		
	NEGLIGIBLE	7.1	7.2	11.1		

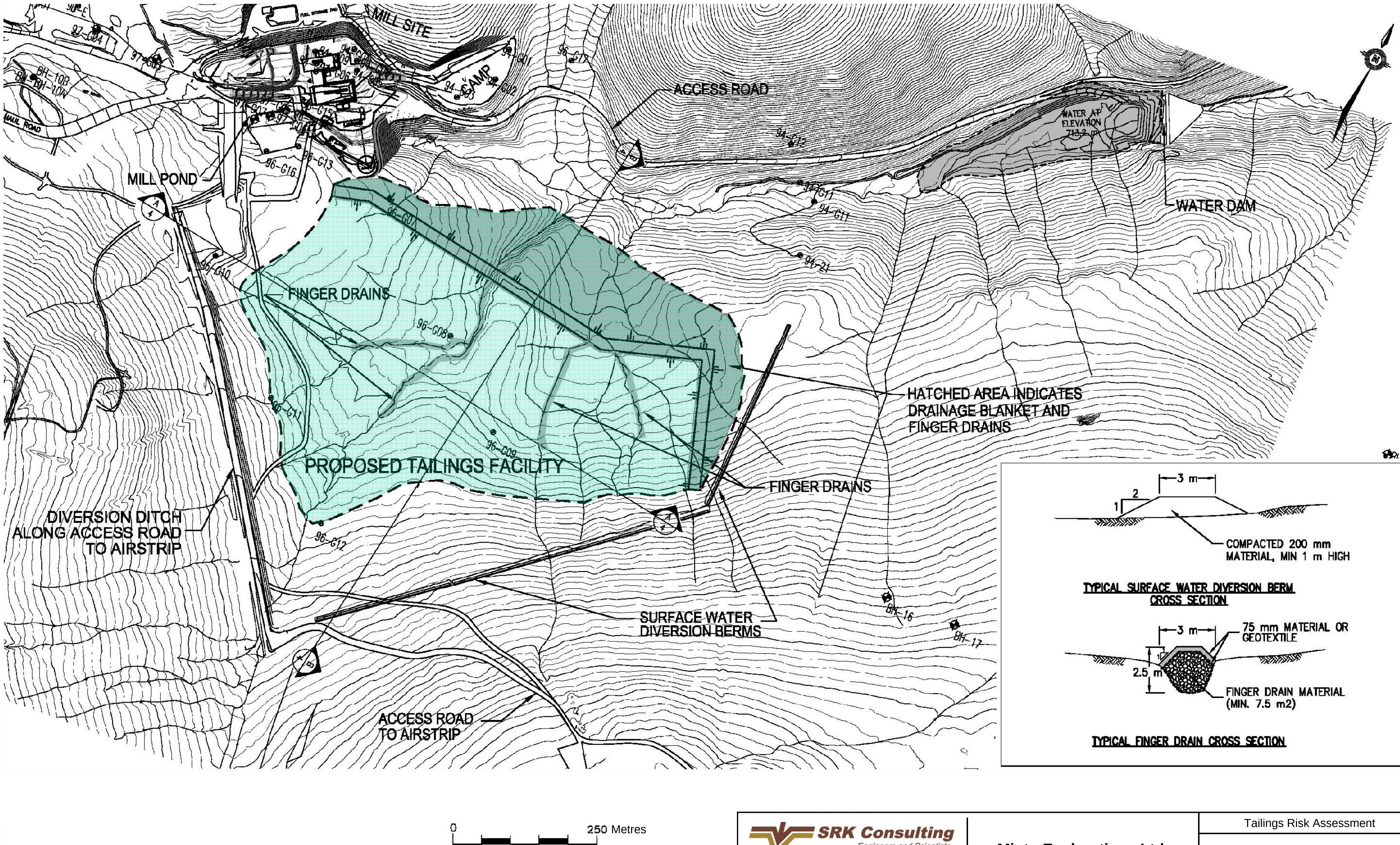
Table 5.5: Risk Matrix for Public Safety Effects

		LIKELIHOOD				
		NOT LIKELY	LOW	MODERATE	HIGH	EXPECTED
SEVERITY OF EFFECTS	EXTREME					
	HIGH					
	MODERATE					
	LOW	1.2, 1.4, 1.5, 2.2, 2.4, 2.5, 3.2, 4.2	1.1, 2.1, 3.1, 4.1, 5.1, 6.1	5.2		
	NEGLIGIBLE	1.6, 2.6, 7.1, 7.3, 8.2, 9.2, 10.1, 10.3, 10.5	1.3, 2.3, 3.3, 4.3, 7.2, 8.1, 8.3, 9.1, 9.3, 10.2, 10.4, 10.6	11.1	11.2	

Figures

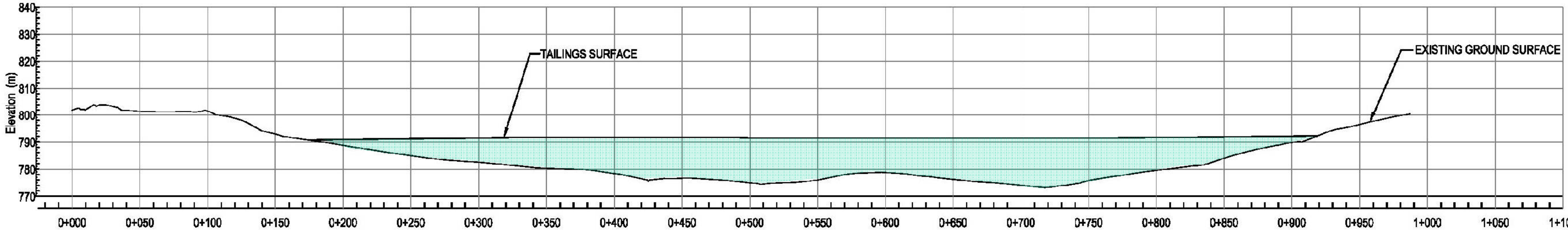


SRK Consulting Engineers and Scientists VANCOUVER	**Minto Explorations Ltd.**	Tailings Risk Assessment **Project Location Map**		
Job No: 2CM022.003 Filename: Figures 1_location_20090212.ppt	Minto Project, YT	Date: February 2009	Approved:	Figure: 1

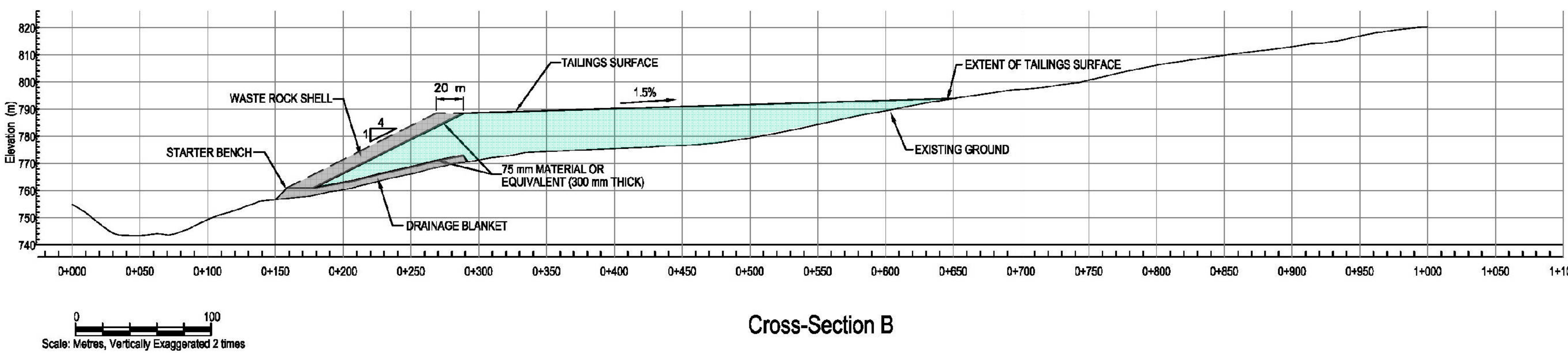


Source: EBA Engineering, Geotechnical Report, "Dry" Stacked Tailings Storage Facility, Minto Mine YT, Figure 3, dated January 5, 2007

SRK Consulting Engineers and Scientists VANCOUVER	Minto Explorations Ltd.	Tailings Risk Assessment
		Tailings Facility Site Plan & Details
Job No: 2CM022.003	Minto Project, YT	Date: February 2009 / Approved: / Figure: 2
Filename: Figures 2-3_tailings_20090212.ppt		



Cross-Section A



Cross-Section B

Source: EBA Engineering, Geotechnical Report, "Dry" Stacked Tailings Storage Facility, Minto Mine YT, Figure 4, dated January 5, 2007

SRK Consulting Engineers and Scientists VANCOUVER	Minto Explorations Ltd.	Tailings Risk Assessment **Tailings Facility Typical Cross Section**
Job No: 2CM022.003 Filename: Figures 2-3_tailings_20090212.ppt	Minto Project, YT	Date: February 2009 / Approved: / Figure: 3

Appendix A

Background Information on Failure Modes and Effects Analyses
(paper by Dr. A. MacG. Robertson, P.Eng., and Shannon Shaw)

RISK MANAGEMENT FOR MAJOR GEOTECHNICAL STRUCTURES ON MINES

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Abstract

Any performance of a geotechnical structure that is outside the expected and design intent for that structure, which results in consequences that are undesirable to the owner or stakeholders of the mine, is considered to be a failure. The potential for failure together with the severity of the consequences determine the risk of such failure. Risk management for major geotechnical structures is a process that involves:

a) assessments off the risk of failure, and
b) implementation of a program of risk mitigation and risk control.

Failure may occur in many forms, ranging from physical failure resulting in collapse, displacement or erosion, chemical failures resulting in contaminant generation and migration, biological failures, resulting in poor vegetation growth or impacts on fish and terrestrial fauna, or social failures resulting in dissatisfied public or regulatory agencies.

Risk assessments are done on a periodic basis, involving processes for the identification of the likelihood of a failure and of the consequences of failure in a process often termed a Failure Modes and Effects Analysis (FMEA). The output from an FMEA can be used to prioritize and manage the implementation of risk reduction measures. For sustained risk management a program of risk assessment and risk mitigation is required under a management structure that provides for adequately skilled and experienced personnel to perform the program and independent internal and external review and audit of the processes.

The paper describes both an FMEA methodology and a risk management program and structure that have been applied by the author on numerous mines.

1.0 Need for FMEA's

Often the effects of a failure can have impacts of different severity with respect to economic impacts, environmental impacts, impacts on health and safety of humans, regulatory impacts or violations and impacts of public concern and censure. Risk concerns exist with regard to all of these potential impacts. The objective of an FMEA is to identify and quantify these risks in order to either avoid, or mitigate them.
FMEA is an acronym for **F**ailure **M**odes and **E**ffects **A**nalysis, and is a methodology for the assessment of 'risk', which is a combination of likelihood and consequences of failure. The goal is to provide a useful analysis technique that can be used to assess the potential for, or likelihood of, failure of structures, equipment or processes and the effects of such failures on the larger systems, of which they form a part, and on the surrounding ecosystem, including human health and safety. The environmental community often uses this type of process for conducting environmental risk assessments and engineers use this type of method to assess the risk of engineered systems. Mining companies can use this assessment method to evaluate the risk that their Closure Plans impose on the surrounding environment, workers and the public. This analysis methodology has been adapted for many applications over numerous industries including 'systems' approach and 'criticality' analysis.

2.0 Use of FMEA's for Risk Management

The FMEA provides the evaluators with the ability to perform a systematic and comprehensive evaluation of potential failure modes of the design/plan in order to identify the potential hazards. The technique is not limited to this but is applied as such in this instance. The FMEA can be used to evaluate the potential for failures of the Closure Plan measures that could result in Biological/Land Use Impacts, Regulatory Impacts/Censorship, Public Concern/Image and Health and Safety Impacts. A risk profile can be developed for each of these concern areas. Once the failure modes and measures with the highest risk have been identified, it is possible to consider mitigation or alternative designs to reduce risks. FMEAs are therefore an essential part of any risk and liability reduction program. The incorporation of FMEA's into a formal audit and review process is further discussed in the second half of this paper.

3.0 Evaluation of 'Risk'

Risk is a function of Likelihood and Consequence

The term 'risk' encompasses the concepts of both the likelihood of failure, or the 'expected frequency of failures, and the severity of the expected consequences' if such events were to occur. Because predictive risk assessment involves foreseeing the future, it is an imprecise art. There is a difference between the risk of a failure, and uncertainty in the estimate of that risk. There are also separate uncertainties associated with both the expected frequency and expected consequences.

Mine closure plans include complex natural and engineered systems involving geology, geotechnics, hydrogeology, hydrology, geochemistry, biology, ecology and social systems. Failure modes exist for each of these systems and as a result of interaction between these systems. Methods for failure risk analyses for geotechnical/geochemical/hydrogeological/biological engineered systems are in the early stages of development in comparison to failure risk analyses used in some other fields of engineering where the potential for failures have been more precisely determined from statistics of equivalent system performance or from probability analyses of deterministic systems. This lack is partly due to the heterogeneous nature of natural geological/geochemical/biological systems and partly due to the lack of any established databases for failures of components of such engineered/natural systems. Often the 'best' estimate of the likelihood of failure of such complex systems is made based on the opinion of suitably qualified and experienced professionals. In essence, such estimates are empirical values based on experience and informed judgement of the apprpriate 'expert' familiar with the design, operations and site conditions. The reliability of the estimate is substantially dependent on the available information, expertise, skill, experience and good judgement of the experts. The scope of the FMEA should be broad to cover the effects of relevant modes of failure, including engineered system failures and natural failures (avalanches, floods, droughts etc.). Factors, to account for the confidence in estimates of the likelihood and consequence, should be included to provide readers with an understanding of the analysts opinion of the reliability of the estimate.

4.0 Detailed Approach

4.1 Overview

This type of FMEA is a top down/ expert system approach to risk identification and quantification, and mitigation measure identification and prioritization. Its value and effectiveness depends on having experts with the appropriate knowledge and experience participate in the evaluation during which failure modes are identified, risks estimated, and appropriate mitigation measures proposed. It is therefore essential that the evaluation team include representatives who understand the geotechnics, hydrology, environmental impacts and regulatory requirements applicable to the engineered and natural systems and their surroundings, as well as the past history of the mine's design, construction, operation and performance.

An example of an FMEA worksheet including a few example failure modes is provided in Figure 1. This FMEA worksheet illustrates the methodology's structured approach for identifying failure modes leading to

FAILURE MODES AND EFFECTS ANALYSIS (FMEA) WORKSHEET - SAMPLE MINE (POST CLOSURE)												
						CONSEQUENCES						
PLAN / AREA	ID	FAILURE MODE	EFFECTS	PROJECT STAGE	LIKELIHOOD	BIOLOGICAL IMPACTS & LAND USE	REGULATORY IMPACTS & CONCERNS	PUBLIC CONCERN & IMAGE	HEALTH & SAFETY	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	MITIGATION/ COMMENTS
TAILINGS DAM		Physical Stability										
	A1	Deep seated failure due to drainage pipe failure (not plugged by concrete)	Embankment sloughing or non breaching failutre - no fatalities	PC	H	L	L	M	L	H		Concrete plug drainage pipe.
	A2.1	Deep seated and or piping failure due to any reason including liner degradation and eventual failure (drain plugged with concrete)	Embankment sloughing and breaching failutre - possible fatalities	PC	L	M	H	H	H	M		Liner expected to deteriorate slowly with numrous small leaks allowing draindown of impoundment without high phreatic surface in dam
	A2.2		Embankment sloughing and non-breaching failutre - no fatalities	PC	L	L	L	M	L	M		
	A3.1	Diversion failure; pond flooding; dam overtopping	Breach of dam and discharge - possible fatalities (assuming PMF capacity in dam)	PC	NL	M	H	H	H			Must check dam capacity to store PMF
	A3.2		Breach of dam and discharge - possible fatalities (assuming PMF cannot be stored in dam)	PC	H	M	H	H	H		H	Must check dam capacity to store PMF; Need to upgrade the diversion or raise dam and upgrade spillway to avoid failure
	A4	Face Erosion; deep gullys; leading to dam sloughing	Sample mine liable for repairs	PC	E	L	M	M	N	H	H	Requires long-term minor but regular maintenance. Waste rock cover reduces erosion potential. Crest berm reduces erosion.
	A5	As above but with failure of custodial care	Gullies not repaired leading to massive gully causing dam breach - no fatalities	PC	L	M	L	L	L			Assumes that new custodian will be told by sample mine of maintenance needs and new owner undertakes responsibility for such.
	A6	Diversion spillway erosion	Breach and discharge of tailings - no fat	PC	L	L	M	M	N	H		Upgrade ditch to take 1:1000 year flood. Assumes that a concrete shute spillway will be constructed.
		Chemical Stability										
		Salt leaching - pond becomes toxic to livestock (with and without oxidation)	Sick animals - Sample mine sued	PC	E	M	H	H	L	H	H	Increased tailings cover placement over uncovered and thin areas; Investigate oxidation and leaching potential of tailings.
		As above but with cover extended over entire back area	Sick animals - Sample mine sued	PC	L	M	H	H	L	H		
		Surface water does not meet regulatory standards	Fails regulatory standards	PC	E	L	L	L	N	H		Current results have been reviewed by regulatory authorities. Check why regulatory authorities have not expressed concern
		Salt leaching - toxic to plants	Loss of vegatation quality	PC	E	L	N	N	N	H		
		Ground water drainage quality inadequate	Fails regulatory standards	PC	E	H	H	M	L	M	H	Check why, review monitoring results. Regulatory authorities have not expressed concern

Figure 1. FMEA worksheet

undesired events. This may be modified depending on the assessment objectives. The worksheet is organized in columns with the headings 'Mine Area/Component', 'ID', 'Failure Mode', 'Effect', 'Project Stage', 'Likelihood', 'Consequences', 'Level of Confidence' and 'Mitigation/Comments'. Each of these headings is described in the following sections.

4.2 Mine Area/Component

This column provides an area for a description of each area or component of the mine site is being evaluated. This can be an open pit, rock pile, spillway, tailings dam, pipeline etc.

4.3 ID

This is a simple alpha-numeric code that makes ready, quick reference to specific failure modes for each component certain line items much simpler later on. For instance, often the alpha-numeric codes for each failure mode of each component are plotted within the Risk Matrix graphic as illustrated in Figure 2 (discussed further below) in order to provide a summary of the entire FMEA.

4.4 Failure Mode

A failure mode can be naturally initiated (e.g. an 'act of God' such as an earthquake which is greater than the design event) or it can be initiated by the failure of one of the engineered subsystems (e.g. instability of a dam) or result from operational failure (e.g. failure to close a valve releasing contaminating fluids). Because of the large number of potential failure modes that could be included in an FMEA, it is often necessary to confine evaluations to those that represent a significant risk. Failure modes can also be combinations of events where a small trigger event sets off a chain of events resulting in substantial or large consequences.

The examples provided in the worksheet (Figure 1) relate to the stability of a tailings dam but later parts of the same FMEA relate to other failure modes such as generation of acid rock drainage from the tailings dam as well as facilities such as open pit mine walls and mine rock piles. Some of the failure modes are simply acts of nature (e.g. acidity generated from a pit wall) whereas others may be failure modes related to ineffective or inadequate control measures (e.g. inadequate control of erosion or inadequate blending of non-acid and acid generating materials).

4.5 Effects or Consequences

The assessment of the magnitude of the Effects (or Consequences) of specific failure modes should be based on evaluations or analyses of the systems responses following failure. Adverse effects may have physical, biological or health and safety consequences. It is often necessary to make first estimates of consequences based on a professional judgement of the anticipated impact of that failure. The examples related to acid generation provided in the sample FMEA worksheet would have an effect on the requirements for collection and treatment, or the appearance of contaminated seepage in unexpected areas. The classification of the severity of effects (i.e. the consequences) are discussed under the heading 'Consequences' below.

4.6 Project Stage

Some 'risks' have a different likelihood of occuring or a different consequence if they occur during operations (O) or post closure (PC). The column 'Project Stage' is included to indicate the time frame(s) in which the risk was considered. Some risks increase with the period over which the risk is assessed. I.e. the potential of a 100 year recurrence interval flood occuring is much greater during the long post closure period than it is during a, say, 10 year operating life of a mine. Risk of some facility failure (e.g. a spillway) may be greater post closure when there is not an operating staff to provide monitoring and maintenance.

The time frame is also important when assessing risks to human health and safety where there are likely many more people at risk during operations than post closure.

4.7 Likelihood

The likelihood of the failure mode leading to the effects has been classified here using a 5 class system, ranging from not likely to expected (see Table 1). Two separate likelihood distributions have been adopted: one for safety consequences, and another for environmental and public concern consequences. The reason for this is that we have found that, in general, the public tolerance for safety consequences is much lower, and therefore the acceptability of risk of a safety event compared to an environmental event is lower. The number of classes, can be adapted to best suit a specific site.

Table 1. Likelihood of Risk

Likelihood Class	**Likelihood of Occurrence for Safety Consequences (events/year)**	**Likelihood of Occurrence for Environmental and Public Concern Consequences (events/year)**
Not Likely (NL)	<0.01% chance of occurrence	<0.1% chance of occurrence
Low (L)	0.01 - 0.1% chance of occurrence	0.1 - 1% chance of occurrence
Moderate (M)	0.1 - 1% chance of occurrence	1 - 10% chance of occurrence
High (H)	1 - 10% chance of occurrence	10 - 50% chance of occurrence
Expected (E)	>10% chance of occurrence	>50% chance of occurrence

4.8 Consequences

For each effect, the consequence can be assessed separately in each of four different concern areas. For each concern area, there are various scales and thresholds that may apply, such as scales based on the severity of injury, community well-being, environmental impact, operational impact etc. The scales that we have found most applicable for mine closure assessments are provided on Table 2 below.

For mine closure purposes, the authors have found it useful to have separate consequence categories for each of the following concern areas:

1. Biological Impacts/Land Use
2. Regulatory Impacts and Censure
3. Public Concern and Image Impacts
4. Health and Safety

Regulatory impacts have been found to have a profound influence on risk. Changes in regulation or regulatory enforcement practices following failures, or perceptions of potential failures can have severe consequences. Public concern and activism following failures have also had severe impacts, including impacts on public company share value and abilities to permit new mines.

The consequence ranking, or severity, is typically also classified using a 5 class system. We have found ranking from negligible to extreme consequences to be effective and intuitive. The class intervals for each of the categories is outlined in Table 2. Again, these are suggested classifications that have been found useful in the past, but could be adapted to best suit the site or plan being evaluated at the time.

4.9 Level of Confidence

There is uncertainty regarding both the likelihood of failure and consequence estimates based on a number of factors, including: lack of data; lack of system understanding; uncertain future operating conditions or uncertain maintenance; and, regional development post closure. Thus confidence in the risk estimates may range from low to high. It is useful to reviewers of the FMEA if the evaluation team provides their assessment of their confidence in any risk rating that they conclude.

We have found that a three interval classification system of low, medium and high confidence in the risk ratings is usually adequate and appropriate. Where there is low confidence in a high risk assessment value, this clearly indicates a need to further evaluate the risk in order to more reliably predict both the risk and the mitigation measures to reduce such risk.

Table 2. Severity of Effects

Consequences Severity	Biological Impacts and Land Use	Regulatory Impacts and Censure	Public Concern and Image	Health and Safety
Extreme (>$10M)	Catastrophic impact on habitat (irreversible and large)	Unable to meet regulatory obligations; shut down or severe restriction of operations	Local, international and NGO outcry and demonstrations, results in large stock devaluation: severe restrictions of 'licence to practice'; large compensatory payments etc.	Fatality or multiple fatalities expected
High ($1-$10M)	Significant, irreversible impact on habitat or large, reversible	Regularly (more than once per year) or **severely** fail regulatory obligations or expectations - large increasing fines and loss of regulatory trust	Local, international or NGO activism resulting in political and financial impacts on company 'license to do business' and in major proceedure or practice changes,	Severe injury or disability likely: or some potential for fatality
Moderate ($0.1-$1M)	Significant, reversible impact on habitat	Occasionally (less than one per year) or **moderately** fail regulatory obligations or expectations fined or censured	Occasional local, international and NGO attention requiring minor proceedure changes and additional public relations and communications	Lost time or injury likely: or some potential for serious injuries; or small risk of fatality.
Low ($0.01-0.1M)	Minor impact on habitat	Seldom or **marginally** exceed regulatory obligations or expectations. Some loss of regulatory tolerance, increasing reporting.	Infrequent local, international and NGO attention addressed by normal public relations and communications	First aid required; or small risk of serious injury.
Negligible (<$0.01M)	No measurable impact	No measurable impact	Do not exceed regulatory obligations or expectations	No local/international/ NGO attention

4.10 Mitigation/Comments

For each of the risks, safeguards that are already in place through design or operating procedures can be listed (usually as a separate column). Safeguards act to prevent, detect, or mitigate a risk from reaching its worst results, and can be applied to both the failure mode and the resulting effects. The existing safeguards reduce the likelihood of the risk from occurring.

Similarly, if a particular failure mode and effect is rated a 'high' or 'expected' likelihood and a 'high' or 'extreme' consequence in any of the categories evaluated, additional mitigation measures may be sought to reduce this risk. In this manner, the FMEA worksheet can act as a template from which risk management measures or procedures can be prioritized.

5.0 Presentation of Results

Given the likelihood and severity, a risk rating can be determined and displayed by plotting the results on a two dimensional risk matrix (see Figure2 below). This procedure is often referred to as 'binning'. A failure mode which is 'expected' and would result in an 'extreme' consequence plots in the red 'bin'. The risk ratings are shown as colors alone, to indicate that this is not a mathematically precise representation of risk. The level of 'risk' increases moving from the bottom left to the top right. The warm colors (yellow through red) indicate failure modes with significant and increasing risk ratings. These are the failure modes in most urgent need of determination of mitigation measures. The cold colors (green through dark blue) indicate the failure modes with moderate to low risk.

For ease of communication, the alpha-numeric codes (ID) of the various failure modes can be plotted within the risk matrix easily flagging those ID codes with their associated risk ratings. The resulting plots are called 'Risk Matrices'. Separate matrices are plotted for each of the concern areas. The four risk matrices represent the 'risk profile' for the closure plan being evaluated. A typical profile is provided by plotting the risk matrices for each of the concern areas. Comparison of these matrices indicates that for the example given, the matrix for Regulator Impacts and Censure has the highest risk ratings. These risk matrices (the risk profile) is an excellent tool for illustration to management, regulators and the public the risk profile for a project or its alternatives, as well as for planning risk management programs. In addition, the authors typically color-code the FMEA worksheet using the same color combinations as in the risk matrix, providing a tool with which the reader can scan a long list of evaluated risks and easily pick out those of most concern.

6.0 Risk Management through Audit and Review

Technical Audits and Reviews are completed in order to review the safety, stability and environmental liability of mine facilities such as tailings systems, sediment dams and waste dumps; to identify the safety, stability and environmental liability risks of each structure; and, to provide recommendations for the improvement of safety measures and procedures to enable appropriate international standards to be achieved.

These Audits and Reviews are typically completed by professional specialists and consist of:

- Information collection, review and analysis of all site investigation (geotechnical, hydrology, hydrogeology, geochemistry, environmental and socio-economic), design and 'as-built' plans and reports;
- Field inspection of the sites and structures;
- Review of the operating history and compliance of the structure/facility, operating plans, management systems, emergency response plans and closure plans;
- Identification of the relevant risks for each of the structures;
- Completion of an FMEA for the structure/facility;
- Development of recommendations to mitigate the risks and address issues identified;
- Prioritization of the mitigation measure into a ‘Risk Management Plan’; and
- Preparation of a report summarizing the work.

There are various levels at which an Audit and Review can be completed. At a minimum, a level sufficient to determine the current status of safety, stability and environmental liability of the subject structures is completed. Also included in the Audit and Review is a definition of a path forward for the implementation of measures that would ensure achievement of international standards of good practice and to prioritize the items of a risk reducing action plan. Recommendations for remediation or improvements are typically provided, in which the levels of concern or risk that are associated with deficient items are indicated. For this purpose review ratings that describe the assessment of where current structures or operational procedures meet appropriate standards, or should be improved, are provided.

	LIKELIHOOD				
CONSEQUENCE	NOT LIKELY	LOW	MODERATE	HIGH	EXPECTED
EXTREME	B14.1, B15.2, B16.2	A42.2, A57, A81.6, B14.1, B14.2, B15.2, B16.2, B91.2, B91.3	A81.2, B92.3, B93.2, B93.3	A56, B15.1, B16.1, B91.1	
HIGH		A101.3	A12.3, A63.3, B11.2, B11.3, B13.1, B13.2,	B11.1	B81.1
MODERATE	B17	B17, B92.1, B92.2, B93.1	A63.3, B12.1, B18	A63.4, B12.2, B55.2	B81.3, B81.4, B94.1, B94.2
LOW		A13, A22.2, A61.5, A92.2, A92.5, B85	A101.4	A53.2, A55.2, A61.4, A61.6, A71.1, A71.2, A81.4, A81.5, A92.3	A14.1, A54, A63.1, A63.2, A81.3, A92.1, A92.4, A92.6, B51, B52, B53, B71.1, B71.2, B81.2
NEGLIGIBLE		A41.2, A41.4, A41.7, A42.2, A61.1, A63.5, A101.2, A101.6, B21.1, B22.1, B23.1, B31.2, B31.3, B31.4, B31.5, B31.6, B33.4, B33.5, B33.6, B34.1, B37.1, B41.1, B41.2, B41.3, B41.4	A21.1, A21.2, A22.1, A41.5, A41.6, A52, A61.2, A62, A81.1, B31.1, B32.2, B33.1, B36.1	A12.2, A41.1, A41.3, A53.1, A55.1, B31.3, B33.2, B33.3	A11, A12.1, A14.2, A41.8, A42.1, A61.3, A91, A101.5, A101.7, B21.2, B22.2, B23.2, B32.1, B34.2, B35.1, B35.2, B36.2, B37.2

Figure 2. Example Risk Matrix for Health and Safety (ID's for various failure modes are plotted in the corresponding matrix locations).

7.0 Definitions for Audit and Review Levels and Terminology

Four levels of Audit and Review are defined:

1. **Audit level:** At this level the auditor performs sufficient investigation, documentation and analysis review to develop an independent opinion on both the general principles of designs, construction and operations and on the validity of the key elements of the design analyses, construction control and operating methods. For dams and critical mining structures, Audits are typically conducted at fairly widely spaced intervals of about 5 years. More frequent Audits may be appropriate if the structure and designs are undergoing rapid and substantial change. Generally an audit level review is required on initiation of the review process for any major structure. An Audit Report is produced which documents, generally against a check list, the reviewer's observations as to adequacy of the designs, construction and operations and indicates any recommendations that flow from these. The adequacy of the design is based on its achievement of a set of standards as defined below.

2. **Review level:** At this level the reviewer generally reviews all key documents and does at least 'reasonableness of results' checks on key analyses, design values, and conclusions. Design, construction and operational procedures are reviewed at a level sufficient to develop an independent opinion of the adequacy and efficiency of the designs, construction and operations. The reviewer generally relies on the representations made to the reviewer by key project personnel, provided the results and representations appear reasonable and consistent with what the reviewer would expect. A review report is produced which documents the reviewer's observations as to adequacy of the designs, construction and operations and indicates any recommendations that flow from these.

3. **Review at Discussion level:** At the discussion level the reviewer is not provided with all the relevant data required to perform an independent assessment or develop an independent opinion. Generally, only selective information is presented, often in meeting presentation form, and there is insufficient time to absorb and digest all the pertinent information and develop a through understanding of all pertinent aspects relating to the design, construction and operation. The reviewer relies on information selected by the presenter and substantially on the observations, interpretation and conclusions of the presenters. While discussion level reviews are valuable in that the reviewer can question results, conclusions and design aspects that raise issues in the mind of the reviewer, and make recommendations when applicable, the reviewer is often unable to develop an in depth understanding of all the issues that may arise or an independent opinion.

4. **Interim Reviews:** Interim reviews are conducted between more formal regularly spaced reviews. They are generally conducted during periods when there is rapid change in the designs or construction of major geotechnical structures and may be focused on only those parts of the design or structure which are undergoing change. They form a basis for regular exchange of information between the design/construction/operating personnel and the reviewer and for reviewer comments during the process of design/construction or operation.

8.0 The Audit or Review Process

8.1 Overview

The auditor and/or reviewer generally evaluates each structure and facility of a mine development and makes an assessment of the adequacy of the design, construction, operation and closure provisions for that facility according to some check list. Examples of checklists are available from a number of sources such as the MAC Guide to the Management of Tailings Facilities and in M.B. Szymanski's (1999) Evaluation of Safety of Tailings Dams. Modified tables/checklists for review used by the authors are provided in Tables 3 and 4.

For each structure or facility, the various design, construction, operation and closure elements are reviewed and an assessment made of the adequacy of standards achieved. This results in the assignment of a Review Rating as described below. Many reviews are concluded once the Review Rating is complete. The author recommends that in addition, a risk assessment be completed using the FMEA process to enable a program and a prioritization of risk reduction to be implemented. The risk that is associated with any structure or facility that does not achieve appropriate standards is dependent on the likely consequences. The reviewer therefore assigns a Consequence Category in addition to the Review Rating. A definition of Consequence Categories is provided below. Finally, the reviewer considers both the Review Rating and the Consequence Classification and makes a judgement decision of the risk and assigns a Risk Management Rating as defined below. This rating allows the prioritzation of actions required to reduce and manage risk, and the definition of Risk Management Plan.

8.2 Review Ratings

The review rating is an assessment of the extent to which the current status of design, construction, operation or closure measures meet typical international standards of good practice and design standards. The review is completed using the following ratings:

Blank - Undone, or inadequate information for a rational assessment
NA - Not applicable
I - Improvement needed to meet current international good practice or standards
I$^-$ - Large and urgent improvement needed to meet required practice or standards
I$^+$ - While inadequate against international standards, there are mitigating circumstances reducing concerns.
P - Passes test of adequacy (generally reasonable international standards)
P$^-$ - While passing there are substantial concern issues
P$^+$ - Passes well to consistent high standards
O - Has been optimized to beyond standards, to minimize risk
O$^-$ - Optimization is preliminary or not well done
O$^+$ - Optimization is extensive and risks have been minimized.

Review ratings do not include the assessment of the failure risks associated with the current state.

8.3 Consequence Classification Category

Consequence categories consider only the severity of the potential impacts should failure occur. They provide some indication of the importance of applying an appropriate level of design, construction, operation and closure engineering and management to the particular element or system being evaluated. High levels of risk management must be applied to avoid failure where there are severe consequences.

The consequence is similar to the 'hazard ranking' and may include for financial, investor and public relations consequences in addition to human health and safety and environmental impacts.

The scale is a 1 to 5 scale as follows:

1. very low impacts: No injuries or identifiable health effects, insignificant property damage or environmental impact
2. mitigatable low to moderate impacts: only minor injuries and minor property damage, small temporary environmental impacts
3. moderate impacts: injuries anticipated, reversible health and environmental impacts of moderate extent and moderate property damage.
4. severe impacts: severe injuries, possibly a fatality, large property damage, substantial but reversible environmental impacts or irreversible but moderate environmental impacts.
5. extreme impacts: multiple fatalities, extensive property damage, and extensive environmental impact

There are numerous other hazard and consequence category scales that may be used to obtain a ranking which may then be used assigned a 5 point scale as listed above. The authors recommend the performance of an FMEA for this purpose.

8.4 Risk Management Ratings

The risk management ratings provide an assessment of the current and future failure risk that exists for the current state of the element or system. It is the objective of a risk management program to reduce risks to levels consistent with regulatory requirements and corporate objectives.

For the purposes of risk management a Risk Rating is required. In the conducting of Reviews and Audits the authors have found the Concern/Risk Rating provided below to be useful for conveying to the mining company or stakeholders an understanding of the level of risk and concern, and the urgency for risk reduction. Such a risk rating, provided for each major element of the tailings pond, indicates to the operator and stakeholders the reviewers opinion of the degree of concern/risk and provides a priority list and time scale for correction.

The following risk rating is bases on the assumption that risk is proportional to:

- Site specific or inherent risk;
- Application of Internationally accepted criteria, standards, guidelines and methods;
- Demonstrated precedent;

- Capability, ability and commitment of design, construction and operating staff;
- Monitoring for unexpected behaviour;
- Available response time and methods; and
- Operational and risk management

At the most comprehensive level of risk assessment, a conventional risk assessment (FMEA) can be performed for elements of the facility to determine site specific or inherent risk. This establishes the appropriate design, construction and operating criteria, standards and methods. In the absence of a formal risk assessment, an experienced practitioner makes a judgment of risk.

Level 1: Low Risk/Concern

General criterion:

- Failure has only very low impacts, or
- Design, construction and operations are to appropriate high standards.
- Only normal care and management are required to maintain low risk.

Detailed criteria:

Failure of the facility will not result in significant injury, loss of life or environmental damage: or risk is low as determined by all of the following evaluation criteria:

1. Site specific and inherent risks have been identified and provided for in design, construction and operations.
2. Design, materials, construction and operating methods are in accordance with internationally accepted design criteria, standards, guidelines and methods for facilities of this type.
3. The facility is designed, constructed and operated by personnel with appropriate experience, training, commitment and authority.
4. There is precedent for all facility elements (size, materials, performance levels, etc), construction and operating conditions.
5. Facility performance is monitored, and detection of unexpected behavior is expected with a high level of confidence.
6. Potential instability or unexpected behavior will develop sufficiently slowly to allow reliable corrective measures to be implemented.
7. A reliable, informed management structure and procedures are in place to implement and control all aspects of facility design, construction and operation.

Risk Management:

This is the lowest level of risk. Risk management is primarily aimed at maintaining this level while optimizing opportunities for further reduction.

Level 2: Small Risk/Concern

General criterion:

- Failure would result only in mitigatable low to moderate impacts, or
- Design, construction and operation have minor deficiencies that are correctable.
- Some increased risk management is required during period of correction.

Risk Management:

Risk reduction to level 1 is desirable and should be implemented as part of the on-going design, construction and operating optimization program for the facility.

Level 3: Medium Risk/Concern

General criterion:

- Failure would result in only moderate impacts, or
- Design, construction and operation have moderate deficiencies that are correctable with directed management.
- Committed risk management is required during period of correction.

Risk Management:

Continued implementation of design, construction or operation should proceed under a specific risk management plan that ensures risks can be managed to acceptably low levels while corrective measures are implemented. Reduction to Risk Level 1 should be planned for.

Level 4: Substantial Risk/Concern

General criterion:

- Failure could result in severe impacts, or
- Design, construction and operation deficiencies are major but correctable with directed management.
- Comprehensive and committed risk management is required during period of correction. Correction is required urgently but not on a crisis level.

Risk Management:

Continued implementation of design, construction or operation should proceed under a specific risk management plan. It may not be feasible to manage risks to acceptably low levels while corrective measures are implemented. Aspects for which acceptably low levels of risk cannot be achieved should be delayed or ceased until corrective measures are implemented. If this is not feasible (due to facility conditions) then specific risk minimization measures must be defined and implemented. Reduction to Risk Level 1 should be planned for.

Level 5: High Risk/Concern

General criterion:

- Failure could result in extreme impacts, or
- Design, construction and operation deficiencies are major and it is uncertain if they are correctable with directed management.
- A high level of focused and committed risk management is required during period of correction.
- Correction is required on a very urgent, possibly crisis level.

Risk Management:

Continued implementation of design, construction or operation should proceed under a specific risk management plan. It may not be feasible to manage risks to acceptably low levels while corrective measures are implemented. Aspects for which acceptably low levels of risk cannot be achieved should be delayed or ceased until corrective measures are implemented. If this not feasible (due to facility conditions) then specific risk minimization measures must be defined and implemented. Reduction to Risk Level 1 should be planned for.

9.0 Risk Management Program

A Risk Management Program involves: (i) the systematic application of current international standards of good engineering practice for the investigation, design, construction, operation and closure of mining structures, as well as (ii) the implementation of a regular program of inspection, supervision, and monitoring to well defined operating and performance objectives documented in design, operating and closure manuals, and (iii) a regular program of Audit and Review resulting in the definition and implementation of a Risk Management Plan.

10.0 References

Szymanski, M.B.: Evaluation of Safety of Tailings Dams. BiTech Publishers Ltd., 1999.

The Mining Association of Canada. A Guide to the Management of Tailings Facilities. September 1998. (http://www.mining.ca/english/publications/tailingsguide.pdf)

Table 3. Dam Safety and Environmental Liability Review Checklist

TAILINGS DAM REVIEW	**REVIEW RATING**	**RISK MANAGEMENT RATING**	**REVIEW COMMENTS**	**RISK MANAGEMENT COMMENTS**
General Information				
Name of Dam				
Location				
Type of dam:				
Consequence Classification Safety				
Consequence Classification Environmental				
Review Background				
Inspected by:				
Reviewed and approved by:				
Inspect. date and weather conditions:				
Site investigation (Geo, Hyd, Geochem, Geohyd)				
Materials characterization (Physical Chemical)				
Design report & standards (Floods, Stability, Containment)				
Design/as-built data available:				
Operating manual/Training				
Emergency response				
Closure plan & financial ass.				
Inspection & review plan				
Reviewed by authorites				
Compliance Record				
Review Record				
Purpose of dam:				
Date of last DSI:				
Date of last DSR:				
Initial dam construction date:				
Original dam engineered:				
Type of dam:				
Relation to tailings basin:				
Watershed and diversions:				
Typical dam section:				
Approx dam length and max. height:				
Tailings pond adjacent to dam:				
Typical tailings pond length/size:				
Freeboard at time of DSI:				

Table 3. Continued

TAILINGS DAM REVIEW	REVIEW RATING	RISK MANAGEMENT RATING	REVIEW COMMENTS	RISK MANAGEMENT COMMENTS
Minimum past freeboard:				
Discharge structure:				
Emergency discharge structure(s):				
Date of last raise of dam:				
Future dam raise planned:				
Dam instrumentation/conditions:				
Volume and type of solids stored:				
Tailings disposal method:				
Tailings production rate, capacity				
Operating data review				
Environmental monitoring review				
Special 'as-built' features:				
New developments d/s of dam:				
Dam failed since last DSI:				
Overall Review Conclusions				
General condition of dam:				
Next DSI or DSR recommended:				
Overall Risk Rating				

Table 4. Inspection of Dam Structure

Observed Features	Yes	No	Photo No.	Comment / Note No.
1.0 (visible part of) Upstream Slope				
1.1 Erosion protection				
1.2 Evidence of erosion				
1.3 Evidence of movement				
1.4 Evidence of sloughing				
1.5 Evidence of cracking				
1.6 Mark of high pond level				
1.7 Taikings adjacent to dam				
1.8 Vegetation				
1.9 Slope visually uniform				
1.10 Other unusual conditions				
1.11 Evidence of repairs				
2.0 Crest				
2.1 Breach / wash-out				
2.2 Lateral movement				
2.3 Evidence of settlement				
2.4 Evidence of cracking				
2.5 Shoulder erosion				
2.6 Reduced width				
2.7 Crest visually horizontal				
2.8 Other unusual conditions				
2.9 Evidence of repairs				
3.0 Downstream Slope				
3.1 Erosion protection				
3.2 Evidence of erosion				
3.3 Evidence of movement				
3.4 Evidence of sloughing				
3.5 Evidence of cracking				
3.6 Signs of phreatic surface				
3.7 Evidence of seepage				
3.8 Seepage clear				
3.9 Evidence of contamination				
3.10 Vegetation				
3.11 Slope visually uniform				
3.12 Other unusual conditions				
3.13 Evidence of repairs				

Table 4 (continued)

Observed Features	Yes	No	Photo No.	Comment / Note No.
4.0 Left and Right Abutments				
4.1 Evidence of seepage				
4.2 Seepage clear				
4.3 Evidence of contamination				
4.4 Evidence of erosion				
4.5 Evidence of cracking				
4.6 Evidence of movement				
4.7 Evidence of settlement				
4.8 Other unusual conditions				
4.9 Evidence of repairs				
5.0 Downstream Toe				
5.1 Toe drain exists				
5.2 Toe drain working well				
5.3 Toe ditch exists				
5.4 Flow in toe ditch				
5.5 Evidence of seepage				
5.6 Seepage clear				
5.7 Evidence of contamination				
5.8 Evidence of vegetat. kills				
5.9 Soft toe condition				
5.10 Evidence of sloughing				
5.11 Evidence of boils				
5.12 Other unusual conditions				
5.13 Evidence of repairs				
6.0 General				
6.1 Associated tailings dams				
6.2 SCF(s) at this dam				
6.3 Decant structure at this dam				
6.4 Embedded/buried structures				
6.5 Spillway at/next to this dam				
6.6 Pipelines at this dam				
6.7 Evidence of AMD				
6.8 Tailings next to dam inspected				
6.9 Crest accessible by truck				
6.10 Public access to dam				
6.11 Any unusual conditions				