MINTO MINE CLOSURE – FAILURE MODES AND EFFECTS ASSESSMENT

2014 WORKSHOP REPORT

FINAL REPORT

December 2014

Prepared for:

MINTO EXPLORATIONS LTD.

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1 INTRODUCTION

In advance of the submission of a Reclamation and Closure Plan (RCP) for the Phase IV mine plan at the Minto Mine, Minto Explorations Ltd. (Minto) conducted a multi-stakeholder Failure Modes and Effects Assessment (FMEA) on a suite of example mine closure scenarios. The workshop was held in Whitehorse in January of 2013, and involved participants representing Minto, Selkirk First Nation (SFN), Yukon Government- Energy Mines and Resources (YG-EMR), and the Yukon Water Board (YWB).

On behalf of Minto, Access Consulting Group has developed and recently submitted an updated Reclamation and Closure Plan (RCP v5.1, August 2014) to support permit amendment applications for the Phase V/VI Expansion mine plan.

Minto hosted a multi-stakeholder FMEA workshop (in two parts) for the Phase V/VI RCP. The first session in Vancouver on August 27 and 28, 2014. A second, supplementary FMEA workshop was held in Whitehorse on October 9 and 10 with a smaller subset of the original workshop group to address outstanding mine components and closure aspects that had not been addressed in the first workshop.

As in January 2013, the FMEA used predefined consequence categories, severity descriptors and likelihood terminology to determine where the residual risk associated with the various mine components ranked on the risk matrix (from Low to Very High). The risk rating tools used in the FMEA workshop(s) is presented in Appendix A.

The terminology adopted for the risk rating tools was modified slightly from the terminology used in the January 2013 FMEA workshop to reflect feedback from a broad range of workshop participants during a pre-workshop teleconference.

The FMEA workshop methodology and agenda, which was also refined during a pre-workshop teleconference, was distributed to workshop participants in advance of the workshop (Appendix B).

This report provides a description of the FMEA objectives and scope, and a summary of the workshop and the outcomes. It should be noted that some of the facilities initially identified for inclusion in the FMEA workshop were, upon further discussion with the broader workshop group, deemed to be relatively low risk and therefore dropped from detailed discussion and formal risk ranking exercise.

2 WORKSHOP OBJECTIVES, SCOPE AND APPROACH

The overall objective of the FMEA workshop was to evaluate the residual risks that would remain after implementation of the RCP v5.1.

The FMEA covered the entire Minto mine site and mainly focused on a time frame during Post Closure II as it is described in the RCP v5.1, when all reclamation activities are completed and the site has entered into a phase of primarily monitoring and maintenance.

The Closure FMEA used an approach similar to that utilized in the Preliminary FMEA in January 2013, in which specific combinations of failure modes and resulting effects were rated by participants. The failure scenarios generated in 2013 were revisited at the beginning of this workshop to preserve considerations which were still relevant to the Phase V/VI RCP. Appendix C-1 presents the relevant risk scenarios that were carried over from the January 2013 FMEA workshop. One of the first tasks of the FMEA workshop participants was to determine, as a group, to which facilities the identified risk scenarios would apply.

The FMEA was conducted both on a "Facility" basis (separate risk register for each facility) and on topics that are appropriately addressed on a "Site-Wide" basis. These are generally reflective of the reclamation and closure measures presented in RCP Section 7, and an initial numbered starting list of topic areas included:

Facilities:
1. Underground Workings – subsidence, hydrologic
2. Open Pits
3. Dry Stack Tailings Storage Facility
4. Main Dam
5. Mill Valley Fill Extension
6. Waste Rock Dumps
7. Overburden Dumps
8. Ore Stockpiles and Pads
9. Mine Infrastructure

Site-Wide Topics:
10. Source Control – Waste Covers
11. Water Treatment
12. Water Conveyance
13. Site Access
14. Administrative
15. "Domino Effect" (added by consensus during August workshop)

The columns proposed for each of the above risk registers were:

- Category of failure (as appropriate for facility/topic)
    - water management
    - physical stability

    - chemical stability
    - administration
- Scenario combining failure mode and effect
- Consequence type
- Consequence severity
- Likelihood of occurrence
- Risk Rating
- Notes/ Mitigations

The risk rating tools utilized during the workshop are included in Appendix A.

3 Overview of FMEA Workshop

3.1 FMEA Process

The FMEA was carried out using a consequence-likelihood method, utilizing three risk rating tools (the consequence-severity matrix, the likelihood chart, and the risk matrix) located in Appendix A. A draft agenda and methodology was distributed to all participants for consideration and comment. One week prior to the workshop, a conference call was held which included representatives from Minto, SRK, SFN, and Access, to discuss and refine the methodology so as to maximize the time for risk ratings during the workshop. During this call it was determined that the results of the January 2013 FMEA workshop should be somehow incorporated so as to not lose the information gained from that process. It was agreed that Access would compile the scenarios into a starting table to evaluate at the beginning of the workshop.

The final agenda/methodology document (revised through advance participant discussion) is included here for reference as Appendix B.

3.2 Workshop Structure

The workshop began with a review of the approach, and the agreement that the timeframe of the FMEA was to examine risks to the site during the Post Closure II period when all site reclamation work was complete and the site was in a state of monitoring and maintenance. The group agreed to modify the consequence-severity matrix such that a single fatality would result in a "Critical" severity rating, as opposed to a rating of "Major".

A discussion was held regarding the risk matrix and how the process is evaluating annual residual risk. Concern was raised that it was important to consider longer term views. It was noted that there is a distinct difference in significance for a 200-year event to First Nations and to a mining proponent or consultant. It was agreed to move forward on the basis of evaluating annual residual risk, but to acknowledge concern of longer term risks as appropriate and to flag issues for further discussion.

As suggested in the discussions held during the conference call prior to the workshop, the 2013 FMEA risk registry was consolidated onto a single worksheet by Access and given preliminary categories for filing under the various facilities and site wide topics. The group reviewed this preliminary allocation and adjusted if required. The final allocation table is provided in Appendix C. The 2013 risk registry results were then migrated to the appropriate 2014 FMEA risk register with the understanding that the wording of each previous failure mode would be reworked to reflect the current RCP if/as appropriate.

3.2.1 Risk Rating Process

The risk ratings were developed by the group. For each scenario that was rated, potential risks were identified, recorded, and taken through a facilitated procedure using the consequence-severity and likelihood tools to reach a consensus risk rating. The risk ratings were recorded in a risk register spreadsheet that was projected on a screen for participants to refer to and provide feedback on during the meeting, and the resultant risk IDs were placed on a wall matrix and photographed once the topic was complete.

4 FMEA Results

4.1 August Workshop

The first FMEA workshop was held at SRK's office in Vancouver, BC on August 27 and 28, 2014. The workshop was facilitated by Dr. Dirk Van Zyl (Chair of Mining and the Environment at the Norman B. Keevil Institute of Mining Engineering, University of British Columbia). The two-day workshop included participation by representatives of Minto, SFN, and YG-EMR. Representatives from Norwest Corporation (in its third party review capacity on geotechnical subjects at Minto Mine, on behalf of Minto and SFN jointly) participated on the second day only (August 28).

The participants are listed in Table 1.

Table 4-1 August FMEA Workshop Participants

Name	Company	Days Attending
Jim Theriault	Access	August 27/28
Ken Boldt	Access	August 27/28
Scott Keesey	Access	August 27/28
Dirk Van Zyl	SRK	August 27/28
Peter Mikes	SRK	August 27/28
Ryan Herbert	Minto	August 27/28
Jennie Gjertsen	Minto	August 27/28
Erin Dowd	YG Mineral Resources	August 27/28
Bill Slater	BSEC	August 27/28
William Sydney	SFN	August 27/28
Cord Hamilton	Northland Earth & Water	August 27/28
Jim Kuipers	KA/SFN	August 27/28
Debbie Trudeau	SFN	August 27/28
Pooya Mohseni	Capstone/ Minto	August 27/28
Dylan MacGregor	SRK	August 27/28
Cam Scott	SRK	August 28
Richard Dawson	Norwest	August 28
David Sego	Norwest	August 28

It was apparent to the participants early in the workshop that the initial list of topics could not be addressed adequately in the two-day allotted timeframe. It was therefore decided by the group that certain facilities and topics were not of sufficient consequence to warrant formal rate by the FMEA process. These topics were removed from the agenda, and included: (1) Underground Workings; (4) Overburden Dumps; (5) Ore Stockpile Pads; (9) Mine Infrastructure and (13) Site Access.

A discussion regarding where to place scenarios that involved a number of facilities and 'cascading' effects led to the creation of a new site-wide topic called "Domino Effect (#15).

Key remaining topics were prioritized for completion in this workshop, and it was agreed that the remaining topics would be postponed to be handled at a future time. Access agreed to construct "strawmen" scenarios for these facilities and topics to present to the larger group to expedite the follow-up session.

The topics rated in the August workshop included:

August 27:

1. Area 2 Pit

9. Source Control – Waste Covers

10. Water Conveyance

August 28:

2/3/6. Main Pit/Main Pit Dump/Main Dam and Spillway

7/8. Dry Stack Tailings Storage Facility and Mill Valley Fill Extension

Topics that were deferred to the supplementary FMEA workshop included:

Facilities:

2. Open Pits (Minto North and Ridgetop South)
3. Waste Rock Dumps (Main Waste Dump, South West Dump, Ridgetop Waste Dump)

Site-Wide Topics:

11. Water Treatment
14. Administrative
15. Domino Effect

4.2 October Workshop

The supplementary FMEA workshop was conducted over two half-day sessions to accommodate scheduling challenges and ensure that key participants with specialist expertise were present for the appropriate discussions. The workshop was jointly facilitated by Dylan MacGregor and Scott Keesey and the same FMEA protocols and risk rating tools that were used in the August workshop were used once again.

As agreed to during the August workshop, participation in the second FMEA workshop was limited to those who had participated in the first workshop. The one notable exception was Steve Januszewski (SJCI), an independent consultant who is intimately familiar with the Minto Site and participated on the 2013 FMEA process. Steve attended on behalf of YG EMR Mineral Resources.

Table 4-2 October FMEA Workshop Participants

Name	Company	Days Attending
Jim Theriault	Access	October 9/10
Scott Keesey	Access	October 9/10
Dylan MacGregor	SRK	October 9/10
Jennie Gjertsen	Minto	October 9/10
Pooya Mohseni	Capstone/Minto	October 9
William Sydney	SFN	October 9
Jim Kuipers	KA/SFN	October 9/10
Debbie Trudeau	SFN	October 9/10
Steve Januszewski	SJCI/YG Mineral Resource	October 9/10
Cord Hamilton	Northland Earth and Water	October 10

As proposed during the August workshop, Access pre-populated the Risk Scenarios with relevant examples from the August workshop and also proposed some additional risk scenarios for the wider group to consider. This provided an efficient starting point and all Scenarios were subsequently vetted and expanded upon during the FMEA workshop.

The afternoon of October 9th was devoted to risk ranking scenarios from the remaining WRDs (Main Waste Dump, Southwest Dump and Ridgetop Waste Dump). The risk rankings from the Main Pit Dump (completed during the August FMEA workshop) were reviewed to help recalibrate the group and reacquaint everyone with the FMEA process. Discussions were also expanded to include backfill dumps (which had previously been removed from planned discussions) as it was considered important to address a potential SFN concern/perception that the proposed overburden backfill activities could be seen as wasting good reclamation materials.

The October 10th session addressed the remaining open pits (Minto North, Ridgetop North), Water Treatment, Administration and “Domino Effect”. With respect to Water Treatment, it was recognized that reclamation research into passive treatment is ongoing and evolving. It was agreed that the Reclamation Research Plan needs to advance further in order to better evaluate reasonable and practicably treatment technologies and there is a need to better define water quality objectives before Water Treatment can be properly evaluated by the FMEA process. The group ultimately decided to not rank Water Treatment scenarios but rather flag this topic as significant and consider addressing residual risks associated with Water Treatment using a different process in the near future.

The results of the FMEA risk ratings completed during the October workshop are presented in Appendix C-3.

The workshop participants also identified a number of “parking lot” issues/concerns that could not be addressed by the FMEA process but which require further consideration. The key issues/concerns raised included:

- Current closure plan is deficient with respect to showing final reclaimed facilities, toes of re-graded slopes and location of secondary and tertiary water conveyance;

- More information requested regarding the status of the Reclamation Research Plan and the Main Waste Dump revegetation trials;

- Trafficability layer is required over the Ridgetop North Pit tailings backfill whereas costing only allows for 0.5m of overburden;

- Need to advance the discussion/determination of what constitutes “reasonable and practicable” passive treatment, establish protocols and revisit the options evaluation;

- SFN reiterated their concern that the consequence category of “Community/Media/Reputation” is biased because SFN are lumped together with groups having other interests and perspective; and

- The current closure plan does not sufficiently address signage and access control. There is a need to retain institutional controls and maintain signage in perpetuity.

5 SUMMARY

The risk registers developed during the workshop are provided in Appendix C. A complete summary of the risk scenarios considered during the August and October FMEA workshops is presented on a single table in Appendix D.

The August workshop rated breach of the Main Dam due to permafrost thaw, settling of the dam leading to tailings release, and general failure to conduct preventative maintenance and corrective actions leading to system failures, as the largest perceived residual risks to the site at closure. The lack of inclusion of long-term operation and maintenance of the site was identified as an important issue to be addressed, as was further assessment of permafrost thaw as it pertains to the closure design, in particular for the Main Dam and associated structures. A number of scenarios were not rated, but identified further investigation was required. Other scenarios were given 'provisional' ratings, which were based on certain assumptions which require confirmation/follow up.

The October workshop, which focused primarily on WRDs and open-pits that had not been addressed during the August workshop, generally found the risk scenarios evaluated to contain relatively low residual risk (i.e., Low to Moderate) and primary mitigative actions identified included implementation of an effective AMP and minor modifications to closure configuration (e.g. regrading to maintain ponds away from spill points).

A summary of all risk scenarios evaluated in the August and October FMEA workshops is presented in Appendix D. The highest overall risks (i.e., High and Very High) identified during the FMEA workshops were associated with Administration (Category 14), Water Conveyance (12) and Waste Rock Dumps (6), with Administrative Failures representing the largest perceived residual closure risk. A recurring theme for mitigating residual risk included the implementation of an effective AMP and long-term care and maintenance program.

The results of the two FMEA workshop sessions, combined with formal RCP review comments will be useful in evaluating the need for modifications or improvements to the RCP in advance of completion of the Phase V/VI permitting process.

6 REFERENCES

Access Consulting Group. 2014. Minto Mine Phase V/VI Expansion, Reclamation and Closure Plan, Revision 5.1. Prepared for Capstone Mining Corp., August 2014.

Access Consulting Group. 2013. Minto Mine Phase IV Reclamation and Closure Plan, Revision 4.0. Prepared for Capstone Mining Corp., September 2013.

APPENDIX A

RISK RATING TOOLS

Table 1. Consequence-Severity Matrix

	Severity Descriptors				
Consequence Categories	**Very Low**	**Minor**	**Moderate**	**Major**	**Critical**
1. Environmental Impact	No impact.	Minor localized or short-term impacts.	Significant impact on valued ecosystem component.	Significant impact on valued ecosystem component and medium-term impairment of ecosystem function.	Serious long-term impairment of ecosystem function.
2. Traditional Use	Some disturbance but no impact to traditional land use.	Minor or perceived impact to traditional land use.	Some mitigable impact to traditional land use.	Significant temporary impact to traditional land use.	Significant permanent impact on traditional land use.
3. Regulatory and Legal	Informal advice from a regulatory agency.	Technical/Administrative non-compliance with permit, approval or regulatory requirement. Warning letter issued.	Breach of regulations, permits, or approvals (e.g. 1 day violation of discharge limits). Order or direction issued.	Substantive breach of regulations, permits or approvals (e.g. multi-day violation of discharge limits). Prosecution.	Major breach of regulation – wilful violation. Court order issued.
4. Consequence Costs	< $100,000	$100,000 - $500,000	$ 500,000 - $2.5 Million	$2.5-$10 Million	>$10 Million
5. Community/ Media/ Reputation	Local concerns, but no local complaints or adverse press coverage.	Public concern restricted to local complaints or local adverse press coverage.	Heightened concern by local community, criticism by NGOs or adverse local /regional media attention.	Significant adverse national public, NGO or media attention.	Serious public outcry/demonstrations or adverse International NGO attention or media coverage.
6. Human Health and Safety	Low-level short-term subjective symptoms. No measurable physical effect. No medical treatment.	Objective but reversible disability/impairment and /or medical treatment injuries requiring hospitalization.	Moderate irreversible disability or impairment to one or more people.	Severe irreversible disability or impairment to one or more people.	Single fatality or multiple fatalities.

Table 2. Likelihood Terminology

Likelihood	Frequency Descriptor 1	Frequency Descriptor 2
Almost Certain	Happens often	High frequency (more than once every 5 years)
Likely	Could easily happen	Event does occur, has a history, once every 15 years
Possible	Could happen and has happened elsewhere	Occurs once every 40 years
Unlikely	Hasn't happened yet but could	Occurs once every 200 years
Very Unlikely	Conceivable, but only in extreme circumstances	Occurs once every 1000 years

Table 3. Risk Matrix

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

APPENDIX B

MINTO MINE FMEA METHODOLOGY AND AGENDA

Minto Explorations Ltd.

Minto Mine Phase V/VI Expansion
Methodology for Closure FMEA Workshop

1 Introduction

In advance of the submission of a Reclamation and Closure Plan (RCP) for the Phase IV mine plan at the Minto Mine, Minto conducted a multi-stakeholder Failure Modes and Effects Assessment (FMEA) on a suite of example mine closure scenarios. The workshop was held in Whitehorse in January of 2013, and involved participants representing Minto, Selkirk First Nation (SFN), Yukon Government- Energy Mines and Resources (YG-EMR), and the Yukon Water Board (YWB). It was recognized that the January 2013 FMEA was preliminary in nature, and that a follow-up FMEA would be appropriate once a set of closure options and measures was established. The Phase IV RCP (ACG 2013) incorporated outcomes from the January 2013 FMEA, and was completed and submitted to regulators in September 2013. The risk register from the January 2013 FMEA was appended to the Phase IV RCP; the follow-up FMEA was not undertaken prior to completion of the Phase IV RCP. In meetings between Minto and SFN since the January 2013 FMEA, the merits of completing the exercise have been discussed numerous times.

Minto has recently submitted an updated Reclamation and Closure Plan (RCP v5.1, August 2014) to support permit amendment applications for the Phase V/VI Expansion mine plan. Minto will host a multi-stakeholder FMEA for the Phase V/VI RCP in Vancouver on August 27 and 28, 2014. As in January 2013, the workshop will be facilitated by Dr. Dirk Van Zyl (Chair of Mining and the Environment at the Norman B. Keevil Institute of Mining Engineering, University of British Columbia). The two-day workshop will include participation by representatives of Minto, SFN, and YG-EMR. Representatives from Norwest Corporation (in its third party review capacity on geotechnical subjects at Minto Mine, on behalf of Minto and SFN jointly) will participate on the second day only (August 28); geotechnical considerations will be discussed most substantially on the second day (August 28) given key participant availability. Follow up sessions will be conducted as and if required.

This document provides a description of the FMEA objectives and scope, and the proposed approach to the workshop. The approach will be reviewed and finalized after input from participants via conference call in advance of the workshop.

2 Workshop Objectives

The overall objective of the FMEA workshop is to evaluate the residual risks that would remain after implementation of the RCP v5.1.

3 Scope and Approach

The FMEA will cover RCP v5.1 and related design elements for the proposed closure measures. Familiarity with the RCP v5.1 document for all participants will be critical to a meaningful contribution to the FMEA workshop. Familiarity with facility design reports referenced in the RCP will also be necessary. Access to all of these reports will be provided via FTP site.

The Closure FMEA will be carried out using an approach similar to that utilized in the Preliminary FMEA in January 2013, in which specific combinations of failure modes and resulting effects were rated by participants. Further details on the proposed method are provided in Section 4.

A series of risk registers will be developed (in table format) during the workshop. The FMEA will be conducted both on a "Facility" basis (separate risk register for each facility) and on topics that are appropriately addressed on a "Site-Wide" basis. These are generally reflective of the reclamation and closure measures presented in RCP Section 7, and will include:

Facilities:

- Underground Workings – subsidence, hydrologic
- Open Pits
- Dry Stack Tailings Storage Facility
- Main Dam
- Mill Valley Fill Extension
- Waste Rock Dumps
- Overburden Dumps
- Ore Stockpiles and Pads
- Mine Infrastructure

Site-Wide Topics:

- Source Control – Waste Covers
- Water Treatment
- Water Conveyance
- Site Access
- Administrative

The columns for each of the above risk registers will be:

- Category of failure (as appropriate for facility/topic)
    - water management
    - physical stability
    - chemical stability
    - administration
- Scenario combining failure mode and effect
- Consequence type
- Consequence severity
- Likelihood of occurrence
- Risk Rating
- Notes/ Mitigations

4 Risk Rating Tools

This section presents the tools that form the basis of the risk rating method proposed for the workshop. The tools include two tables and a risk matrix; draft versions of the tools are shown in Tables 1 through 3.

Table 1 presents six categories of consequences that will be considered along with severity ratings ranging from “Very Low” to “Critical”. For each category, the table includes narrative descriptions of the types of negative outcomes that would be typical for each severity rating; these descriptions will be used for reference during the workshop to help participants determine the appropriate severity rating to be assigned to a scenario.

Table 1. Consequence-Severity Matrix

	Severity Descriptors				
Consequence Categories	**Very Low**	**Minor**	**Moderate**	**Major**	**Critical**
1. Environmental Impact	No impact.	Minor localized or short-term impacts.	Significant impact on valued ecosystem component.	Significant impact on valued ecosystem component and medium-term impairment of ecosystem function.	Serious long-term impairment of ecosystem function.
2. Traditional Use	Some disturbance but no impact to traditional land use.	Minor or perceived impact to traditional land use.	Some mitigable impact to traditional land use.	Significant temporary impact to traditional land use.	Significant permanent impact on traditional land use.
3. Regulatory and Legal	Informal advice from a regulatory agency.	Technical/Administrative non-compliance with permit, approval or regulatory requirement. Warning letter issued.	Breach of regulations, permits, or approvals (e.g. 1 day violation of discharge limits). Order or direction issued.	Substantive breach of regulations, permits or approvals (e.g. multi-day violation of discharge limits). Prosecution.	Major breach of regulation – wilful violation. Court order issued.
4. Consequence Costs	< $100,000	$100,000 - $500,000	$ 500,000 - $2.5 Million	$2.5-$10 Million	>$10 Million
5. Community/ Media/ Reputation	Local concerns, but no local complaints or adverse press coverage.	Public concern restricted to local complaints or local adverse press coverage.	Heightened concern by local community, criticism by NGOs or adverse local /regional media attention.	Significant adverse national public, NGO or media attention.	Serious public outcry/demonstrations or adverse International NGO attention or media coverage.
6. Human Health and Safety	Low-level short-term subjective symptoms. No measurable physical effect. No medical treatment.	Objective but reversible disability/impairment and /or medical treatment injuries requiring hospitalization.	Moderate irreversible disability or impairment to one or more people.	Severe irreversible disability or impairment to one or more people.	Single fatality or multiple fatalities.

Table 2 presents descriptors the will be used to aid participants in assigning a ‘Likelihood’ rating for each scenario. The ‘Likelihood’ rating will be assigned to reflect the participants’ view on the probability both that the failure mode will occur and that the effect will result- a series of terms used to define the likelihood that a consequence (from the previous chart) will be realized. The ‘Likelihood Terminology’ table consists of one column containing likelihood ratings that range from ‘Very Unlikely’ to ‘Almost Certain’, along with four other columns which give examples to guide the selection of the appropriate rating.

Table 2. Likelihood Terminology

Likelihood	Frequency Descriptor 1	Frequency Descriptor 2
Almost Certain	Happens often	High frequency (more than once every 5 years)
Likely	Could easily happen	Event does occur, has a history, once every 15 years
Possible	Could happen and has happened elsewhere	Occurs once every 40 years
Unlikely	Hasn’t happened yet but could	Occurs once every 200 years
Very Unlikely	Conceivable, but only in extreme circumstances	Occurs once every 1000 years

Table 3 presents the 'Risk Matrix' which assigns each combination of severity (Table 2) and likelihood (Table 1) a risk rating. This matrix will be used in the workshop to supplement the recording of the results in the risk registry.

Table 3. Risk Matrix

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

5 Workshop Report

Following the workshop, Minto will compile a report summarizing the workshop methods and outcomes, and will circulate the draft report to the workshop participants for comment. The following is a draft outline for the report.

- Introduction
- Workshop objectives
- The boundaries of the FMEA
- A description of the workshop method
- Products of the workshop
- Comments on draft report by workshop participants

6 References

Access Consulting Group. 2014. Minto Mine Phase V/VI Expansion, Reclamation and Closure Plan, Revision 5.1. Prepared for Capstone Mining Corp., August 2014.

Access Consulting Group. 2013. Minto Mine Phase IV Reclamation and Closure Plan, Revision 4.0. Prepared for Capstone Mining Corp., September 2013.

APPENDIX C

RISK REGISTERS

Original Scenario		2013 Minto Phase IV Closure FMEA - Scenarios Relevant to Phase V/VI	Destination	Consequence		Likelihood	Risk Rating	NOTES
				Type	Severity	Probability	Descriptive	
	1	**Water Management**						
	H	Precipitation higher than expected resulting in failure of water conveyance structures because structures are underdesigned	2,3,6,7,8,10,12,15	Conseq. Costs	Moderate	Possible	Moderately High	assuming 200 yr flood design, note - sensitivity analysis for precip on water quality,
	I	Localized precip > regional => less dilution in downstream in downstream environment resulting in unacceptable water quality conditions downstream of site	10,11	Env. Imp.	Minor	Likely	Moderate	
	A	Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration, leading to ongoing maintenance costs	2W, 3W, 4W, 6W,7W, 8W,12,15	Conseq. Costs	Moderate	Unlikely	Moderate	Need to do landscape design carefully to avoid this failure mode
	B	Undiverted runoff upstream of waste mgmt facilities leads to excessive infiltration into upgradient base of dump, resulting in higher flows of poor quality water and unacceptable water quality conditions downstream	3W, 4W, 7W, 8W,12,15	Env. Imp.	Moderate	Unlikely	Moderate	
	1	Failure of existing TDD leads to erosion/channeling and mobilizing materials off faclility during operations		Env. Imp.	Minor	Almost Certain	Moderately High	
	2	Failure of diversion leads to erosion/channeling through cover and into tailings, mobilizing up to 50 tonnes of tailings all the way to Lower Minto Creek during closure	7W, 12, 15	Env. Imp.	Major	Unlikely	Moderately High	FMEA process for Phase IV should inform next version of RCP - re: inspection frequency and what inspection programs/ instrumentation should look like. Assuming annual inspections (1st 5 years? - Scott to check) Lower Minto Creek is a relatively small and relatively unproductive ecosystem
	A	Tailings seepage collection systems inadequate, leading to unacceptable WQ downstream	2W, 6W, 7W,12	Env. Imp.	Moderate	Possible	Moderately High	design, size, location, construction, operation - all contributors to the potential issue, these need to be thought through more for the mitigation
	B			Conseq. Costs	Major	Possible	High	
	C		3W, 12	Env. Imp.	Minor	Likely	Moderate	minor because pit is downstream
	D	SWD toe seepage collection systems inadequate, leading to unacceptable WQ downstream		Conseq. Costs	Moderate	Likely	Moderately High	Feasiblilty of this collection system questionable - due to ice-rich area and deformations, and no clear segregation from valley flows. Mitigation might be to avoid collection system altogher and focus on treatment of full W15 flow in pit.
	E	Collection of cleaner runoff is inadequate, leading to mixing with water requiring treatment and increased treatment costs	12	Conseq. Costs	Minor	Likely	Moderate	
	A	Seismic or extreme flood event larger than design leads to WSP Dam failure (assumes reduced height), resulting in surge of water and solids into Minto Creek		Env. Imp.	Moderate	Very Unlikely	Low	
	B	WSP Dam (assumes reduced height) maintenance requirements not met, resulting in failure and surge of water and solids into Minto Creek		Env. Imp.	Moderate	Very Unlikely	Low	assumes design with maintenance requirements
	A	Flow rates exceed WTP/surge capacity, resulting in unacceptable water quality downstream	11	Env. Imp.	Moderate	Possible	Moderately High	Mitigation : increase surge capacity and/or operate surge volumes better depending on why surge capacity was overwhelmed
	B			Conseq. Costs	Major	Unlikely	Moderately High	assume worst case - plant/surge exceeded because not sufficient
	C	Contaminant loading exceeds treatment capacity, resulting in unacceptable water quality downstream	11	Env. Imp.	Moderate	Unlikely	Moderate	Function of geochemical source term identification
	D			Conseq. Costs	Major	Unlikely	Moderately High	
	E	Treatment technology ineffective for contaminants of concern, resulting in unacceptable water quality downstream	11	Env. Imp.	Moderate	Very Unlikely	Low	
	F			Conseq. Costs	Major	Very Unlikely	Moderate	
	G	Inadequate capacity for storage of byproducts, leads to costs for removal off site		Conseq. Costs	Moderate	Very Unlikely	Low	
	A	Extreme event leads to failure of conveyance structure upgradient of DSTSF, flow onto DSTSF leading to cover damage and tailings mobilization across top of DSTSF leading to unacceptable water quality conditions downstream	7W, 10, 12, 15	Env. Imp.	Major	Possible	High	upslope key of cover? Pitwall failure should be considered elsewhere in planning. Reducing dependance on manmade structures is desirable-i.e. wingwalls at pit outlets
	B	Leakage from conveyance structure upgradient of DSTSF increases flow subsurface and contaminant loading from tailings leading to unacceptable downstream water quality	7W, 12, 15	Env. Imp.	Moderate	Unlikely	Moderate	these should be designed to reduce leakage/seepage to DSTSF
	2	**Chemical Stability**						
	A	Source water quality (source term) worse than expected and causes unacceptable water quality conditions **downstream of site**	3,7,10	Env. Imp.	Critical	Possible	High	assuming no AMP in place
	B	Source water quality (source term) worse than expected and causes unacceptable water quality conditions **downstream of site**		Env. Imp.	Moderate	Possible	Moderately High	assumed AMP in place so Severity moderate, critical to understand chemistry as fully as possible - reflected in likelihood designation, concern about reliance on AMP
	C			Conseq. Costs	Major	Possible	High	
	D			Spec. Cons.	Moderate	Possible	Moderately High	
	E	Source water quality (source term) worse than expected and causes unacceptable water quality conditions **on site**		Env. Imp.	Moderate	Unlikely	Moderate	

	F		2,3,7,10	Legal Obl.	Major	Possible	High	This could apply to the preceding mode if there were W2 standards in place
	G			Conseq. Costs	Moderate	Possible	Moderately High	
	A	Covers don't perform as designed re: infiltration resulting in unacceptable water quality conditions **downstream of site**	10	Env. Imp.	Moderate	Unlikely	Moderate	Assuming AMP and monitoring will respond to any defects
	B			Conseq. Costs	Major	Unlikely	Moderately High	
	B	Erosion leads to increased infiltration and unacceptable downstream WQ effects	10, 12,15	Env. Imp.	Moderate	Unlikely	Moderate	Risks different for DSTSF than for other facilities, potential effects of erosion still need to be considered in design, maintenance costing, etc.
	A	Bioreactors don't perform as designed - overwhelmed, freeze, resulting in unacceptable water quality conditions downstream	11	Env. Imp.	Moderate	Almost Certain	High	Assumption: effective AMP in place Notes: cryo-concentration in seeps, ice cleaner, residual seeps higher concentration Leslie: make sure that any supporting work here has data - not just stories that they work -i.e. Andre Sobolewski's work at G900 didn't work, but MPERG report still says it does.
	A	Wetlands don't perform as designed - overwhelmed, freeze, resulting in unacceptable water quality conditions downstream	11	Env. Imp.	Moderate	Almost Certain	High	
	B	High flow blow out wetland, causing damage and maintenance requirements, assuming high flows designed to bypass	11, 12	Env. Imp.	Moderate	Unlikely	Moderate	Assumption: peak flows not treated by wetlands - need to understand the implications of this during freshet and also during peak flow events. Wetlands are not designed nor capable of treating peak flows, so this is a significant red-flag for planning - needs very careful consideration.
	C			Conseq. Costs	Moderate	Unlikely	Moderate	Need to understand the implications of this during freshet and also during peak flow events.
	A	Pit Lake Treatment (Non-Flow through Pit)						
	i	Non-flow through Area 2 Pit treatment compromised because of diversion ditch failure, resulting in flow through condition		Env. Imp.	Minor	Possible	Moderate	Assuming pit water quality has moderate initial contamination level - make sure this is covered in AMP. What if WQ in Area 2 pit were higher than anticipated?
	ii	Non-flow through pit treatment does not perform		Env. Imp.	Minor	Possible	Moderate	
	iii	Pit Wall Failure in Area 2 results in wave of water released from pit causing damage to downstream facilities and tailings mobilization from bottom of Area 2 pit		Conseq. Costs	Major	Unlikely	Moderately High	Resolution would be difficult - would mean appropriate sizing of the spillway, locating of facilities downgradient
	B	Pit Lake Treatment (Flow through Pit)						
		Flow through Pit treatment does not perform as expected		Env. Imp.	Minor	Unlikely	Low	Assume treatment expectations consider flow through condition and limitations
		Flow through Pit source term underestimated, resulting in higher than expected loading from pit and unacceptable water quality results downstream	2C	Env. Imp.	Moderate	Unlikely	Moderate	
		Pit Wall Failure in Area 2 results in wave of water released from pit causing damage to downstream facilities and tailings mobilization from bottom of Area 2 pit	2P	Conseq. Costs	Major	Very Unlikely	Moderate	In the flow through pit condition, the downstream channels and facilities would be designed for hitgher flows, so likelihood lower than in the non-flow through condition.
	3	**Physical Stability**						
	A	Geotechnical failure of any waste facility (slope stability) resulting in waste material exposure to water leading to unacceptable water quality conditions downstream of site	2P, 3P, 4P, 6P, 7P, 8P, 11	Env. Imp.	Moderate	Possible	Moderately High	this is a result of there being permafrost considerations under some facilities, and uncertainty associated. Could result from differential settlement of pockets of more moist materials
	B			Conseq. Costs	Moderate	Possible	Moderately High	
	C	Geotechnical failure of any waste facility (differential settlement) resulting in rupture of cover and waste material exposure to water leading to unacceptable water quality conditions downstream of site	2P, 3P, 4P, 6P, 7P, 8P, 10, 11	Env. Imp.	Moderate	Likely	Moderately High	Could result from differential settlement of pockets of high moisture materials. Could be moderated by waste mgmt practices limiting wet waste in waste dumps
	D	Geotechnical failure of any waste facility (slope stability) resulting in debris dam, breaching, mobilizing materials and pulse of water into Main Pit, and sediments/tailings leaving pit, leading to unacceptable water quality conditions downstream of site	2P, 3P, 4P, 6P, 7P, 8P, 10, 11, 12	Env. Imp.	Minor	Possible	Moderate	
	4	**Administrative**						
	A	Failure to implement AMP, resulting in unacceptable water quality conditions downstream	14	Env. Imp.	Critical	Possible	High	
	B	Failure to design an appropriate AMP, resulting in unacceptable water quality conditions downstream	14	Env. Imp.	Major	Unlikely	Moderately High	Important to recognize that AMP is more than just monitoring - but careful identification of potential issues, thresholds and appropriate responses. AMP not just an add-on. Needs to be critical component of closure plan at same detail as rest of plan
	C	Departure from design of engineered structures, resulting in unacceptable water quality conditions downstream	14	Env. Imp.	Major	Possible	High	
	A	General failure to maintain site requirements as required - passive treatment, cover maintenance, etc.	14	Env. Imp.	Major	Possible	High	

	2. OPEN PITS	Consequence		Likelihood	Risk Rating	NOTES
		Type	Severity	Probability	Descriptive	(yellow highlighted notes are conditional risk ratings)
1	**Area 2 Pit**					
W	**Water Management**					
1	Precipitation higher than design asssumption (1:200 yr 24 hr) resulting in damage to outlet structure	Conseq. Costs	Minor	Unlikely	Low	Assumes complete replacement of spillway; review whether climate change (potential for inceased precip) has been allowed for
2	Precipitation higher than design asssumption (1:200 yr 24 hr) resulting in erosion of Ditch 400 channel and damage to toe of Main Dam, leading to breach of dam and release of tailings to lower Minto Creek	Env. Imp.	Major	Very Unlikely	Moderate	
3	Precipitation higher than design asssumption (1:200 yr 24 hr) resulting in erosion of Ditch 400 channel and damage to toe of Main Dam, leading to breach of dam and release of tailings to lower Minto Creek	Trad. Use	Major	Very Unlikely	Moderate	
4	Precipitation higher than design asssumption (1:200 yr 24 hr) resulting in erosion of Ditch 400 channel and damage to toe of Main Dam, leading to breach of dam and release of tailings to lower Minto Creek	Reg. & Legal	Major	Very Unlikely	Moderate	
5	Precipitation higher than design asssumption (1:200 yr 24 hr) resulting in erosion of Ditch 400 channel and damage to toe of Main Dam, leading to breach of dam and release of tailings to lower Minto Creek	Conseq. Costs	Critical	Very Unlikely	Moderately High	
6	Precipitation higher than design asssumption (1:200 yr 24 hr) resulting in erosion of Ditch 400 channel and damage to toe of Main Dam, leading to breach of dam and release of tailings to lower Minto Creek	Comm/Media/Rep	Critical	Very Unlikely	Moderately High	
7	Precipitation higher than design asssumption (1:200 yr 24 hr) resulting in erosion of Ditch 400 channel and damage to toe of Main Dam, leading to breach of dam and release of tailings to lower Minto Creek	Human H&S	Moderate	Very Unlikely	Low	
P	**Physical Stability**					
1	Pit wall failure in Area 2 results in wave of water released from pit causing damage to downstream facilities (ditches, passive treatment system, covers)	Env. Imp.	Moderate	Unlikely	Moderate	-Outlet of pit spillway is ~6m deep, water depth in pit ~35m. -Large degree of uncertainty regarding the likelyhood of failure. -Could be mitigated by sharing of wall stability information
2	Pit wall failure in Area 2 results in wave of water released from pit causing damage to downstream facilities (ditches, passive treatment system, covers)	Conseq. Costs	Moderate	Unlikely	Moderate	Same as above
3	Pit wall failure in Area 2 results in wave of water released from pit and causes a fatality.	Human H&S	Critical	Very Unlikely	Moderately High	Same as above; -Ranking preliminary; Failure has not been evaluated. -If a lower likelyhood option was available, it would have been selected.
C	**Chemical Stability**					
1	Pit water quality at a level that causes unacceptable water quality conditions for water fowl / wildlife	Env. Imp.	Moderate	Unlikely	Moderate	Scenario needs to be evaluated; water quality that could affect water fowl needs to be researched and shared.
2	Pit water quality at a level that causes unacceptable water quality conditions for water fowl / wildlife	Trad. Use	Moderate	Unlikely	Moderate	Same as above;
3	Pit water quality at a level that leads to problematic exceedances of downstream water quality objectives	Env. Imp.	Moderate	Possible	Moderately High	Assumes AMP in place, funded (results in a short term impact)
4	Pit water quality at a level that leads to problematic exceedances of site water quality discharge standards	Reg. & Legal	Moderate	Possible	Moderately High	
5	Pit limnology leads to problematic exceedances of site water quality discharge standards	Env. Imp.	Moderate	Unlikely	Moderate	Scenario needs to be evaluated;
6	Discharge water quality objectives are not met when pit first discharges	Env. Imp.	Moderate	Very Unlikely	Low	Pit water quality assumed to be carefully monitored during the transition stage; (pit takes ~ 3years to fill); Assumes treatment occurs if requried.

7	Discharge water quality objectives are not met when pit first discharges requiring treatment to meet discharge objectives by time of first discharge	Conseq. Costs	Moderate	Possible	Moderately High	Pit water quality assumed to be carefully monitored during the transition stage; (pit takes ~ 3years to fill)
2	**Minto North Pit**					
W	**Water Management**					
1	Positive water balance for pit leads to overtopping and erosion at spill point and sediment release downstream, causing unacceptable sedimentation in Mcginty Creek	Env. Imp.	Minor	Unlikely	Low	This is a good item for inclusion in the AMP. Observations during operations and Post-closure 1 period will be useful in better understanding future fate of MN Pit water balance
2	Positive water balance for pit leads to development of pit lake and results in negative perception leading to negative impacts on traditional land use	Trad. Use	Minor	Possible	Moderate	Could be mitigated through education and information sharing. Discussion by group noted that mitigation of perception is complicated by variability in perceptions among individuals.
P	**Physical Stability**					
1	Massive rapid pit wall failure into pit full of water results in wave of water spilling over rim of pit causing erosion and downstream sedimentation and riparian damage	Env. Imp.	Minor	Very Unlikely	Low	
C	**Chemical Stability**					
1	Pit water quality at a level that causes unacceptable water quality conditions for water fowl / wildlife	Env. Imp.	Moderate	Very Unlikely	Low	Scenario needs to be evaluated; water quality that could affect water fowl needs to be researched and shared. Scenario requires pit to contain water, which is uncertain
2	Pit water quality at a level that leads to problematic exceedances of downstream water quality objectives	Env. Imp.	Moderate	Possible	Moderately High	Assumes AMP does not exist or is not implemented
3	Pit water quality at a level that causes unacceptable water quality conditions for water fowl / wildlife and results in some mitigatable impact to tradtional land use	Trad. Use	Moderate	Very Unlikely	Low	Same as above.
3	**Ridgetop North Pit**					
W	**Water Management**					
1	Erosion of downstream slope due to runoff from covered tailings leads to need for repairs and/or establishment of conveyance structure	Conseq. Costs	Minor	Possible	Moderate	Could mitigated through AMP or addressed in closure plan
2	Settlement of tailings leads to ponding on surface of covered tailings resulting in increased infiltration and leading unacceptable downstream water quality	Env. Imp.	Moderate	Very Unlikely	Low	
P	**Physical Stability**					
1	High wall slope failure leads to cover damage, exposure of tailings and need for cover repairs	Conseq. Costs	Minor	Very Unlikely	Low	
2	Ponding of water within RNPTMF against E/NE overburden wall causes slope instability in overburden	Conseq. Costs	Moderate	Unlikely	Moderate	Could be mitigated by including regrading to eleminate ponding in AMP; could undertake slope stability analysis to evaluate risk of this failure mode
3	Thawing of entrained ice leads to settlement in the pit and ponding of water within RNPTMF against E/NE overburden wall causes slope instability in overburden	Conseq. Costs	Moderate	Unlikely	Moderate	Could be mitigated through appropriate tailings deposition plan
C	**Chemical Stability**					
1	No facility specific scenarios idenfied - covered under '10 Source Control'				#N/A	

	3. WASTE ROCK DUMPS	Consequence		Likelihood	Risk Rating	NOTES
		Type	Severity	Probability	Descriptive	
1	**Main Waste Dump**					
W	Water Management					
1	Precipitation higher than expected resulting in failure of water conveyance structures because structures are underdesigned				#N/A	Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA
2	Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration, leading to ongoing maintenance costs				#N/A	Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA
3	Run-on water from upgradient catchment of MWD increases flow subsurface and contaminant loading from waste rock leading to unacceptable downstream water quality	Env. Imp.	Moderate	Very Unlikely	Low	MWD has limited upgradient catchment area and limited resulting run-on
4	Ponding of water on surface of MWD leads to excessive infiltration, increases flow subsurface and contaminant loading from waste rock leading to unacceptable downstream water quality	Env. Imp.	Moderate	Unlikely	Moderate	Requires failure of AMP to realize the scenario. Can be mitigated by shaping surface to limit ponding; maintenance may be required to restore contouring (if differential settlement occurs) to prevent ponding
P	Physical Stability					
1	Instability results in waste material exposure to water leading to unacceptable downstream water quality	Env. Imp.	Moderate	Very Unlikely	Low	Likelihood supported by stability evaluations in MWDE design report
2	Erosion on steeper portion of MWD leads to loss of cover and results in need for repairs	Conseq. Costs	Minor	Likely	Moderate	Can be mitigated through design and/or O&M plan
3	Die-back of cover vegetation after successful establishment and acceptance leads to erosion, and need for repair	Conseq. Costs	Minor	Possible	Moderate	MWD will have been covered/ planted for several years; appropriate selection of veg species would reduce chance of wholesale die-back. Can be mitigated through design and/or O&M plan
4	Root throw results in increased infiltration over the long term and leads to need for repair	Conseq. Costs	Minor	Unlikely	Low	Can be mitigated through design (including appropriate selection of veg species) and/or O&M plan
2	**Southwest Waste Dump**					
W	Water Management					
1	SWD toe seepage collection systems inadequate, leading to unacceptable WQ downstream				#N/A	Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA
2	Precipitation higher than expected resulting in failure of water conveyance structures because structures are underdesigned				#N/A	Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA
3	Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration, leading to ongoing maintenance costs				#N/A	Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA
4	Run-on water from upgradient catchment of SWD increases flow subsurface and contaminant loading from waste rock leading to unacceptable downstream water quality	Env. Imp.	Moderate	Very Unlikely	Low	SWD has limited upgradient catchment area and limited resulting run-on
5	Ponding of water on surface of SWD leads to excessive infiltration, increases flow subsurface and contaminant loading from waste rock leading to unacceptable downstream water quality	Env. Imp.	Moderate	Unlikely	Moderate	Requires failure of AMP to realize the scenario. Can be mitigated by shaping surface to limit ponding; maintenance may be required to restore contouring (if differential settlement occurs) to prevent ponding. There is a BGM cover on HGW, so ponding+increased infiltration is less likely for HGW
6	Existing pond north of MGW/ south of IROD remains in post-closure and causes community concern	Comm/Media/Rep	Very Low	Almost Certain	Moderate	Will be revisited in detailed design and could be mitigated through education and information sharing
P	Physical Stability					
1	Instability results in waste material exposure to water leading to unacceptable downstream water quality	Env. Imp.	Moderate	Very Unlikely	Low	Likelihood supported by stability evaluations in SWD design report??? Foundation includes permafrost overburden, but the design considered the existing foundation conditions

2	Erosion on steeper portions of SWD leads to loss of cover and results in need for repairs	Conseq. Costs	Minor	Possible	Moderate	Can be mitigated through design and/or O&M plan
3	Die-back of cover vegetation after successful establishment and acceptance leads to erosion, and need for repair	Conseq. Costs	Minor	Possible	Moderate	SWD will have been covered/ planted for several years; appropriate selection of veg species would reduce chance of wholesale die-back. Can be mitigated through design and/or O&M plan
4	Root throw results in increased infiltration over the long term and leads to need for repair	Conseq. Costs	Minor	Unlikely	Low	Can be mitigated through design (including appropriate selection of veg species) and/or O&M plan
5	Root throw results in damage to engineered cover (BGM) over HGW leads to increased infiltration over the long term and leads to need for repair	Conseq. Costs	Minor	Possible	Moderate	Can be mitigated through design (including appropriate selection of veg species) and/or O&M plan
3	**Ridgetop Waste Dump**					
W	Water Management					
1	Precipitation higher than expected resulting in failure of water conveyance structures because structures are underdesigned				#N/A	Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA
2	Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration, leading to ongoing maintenance costs				#N/A	Not rated due to absence of upgradient catchment by design
3	Run-on water from upgradient catchment of RWD increases flow subsurface and contaminant loading from waste rock leading to unacceptable downstream water quality				#N/A	Not rated due to absence of upgradient catchment by design
4	Ponding of water on surface of RWD leads to excessive infiltration, increases flow subsurface and contaminant loading from waste rock leading to unacceptable downstream water quality	Env. Imp.	Moderate	Very Unlikely	Low	Requires failure of AMP to realize the scenario. Can be mitigated by shaping surface to limit ponding; maintenance may be required to restore contouring (if differential settlement occurs) to prevent ponding.
P	Physical Stability					
1	Instability results in waste material exposure to water leading to unacceptable downstream water quality	Env. Imp.	Moderate	Very Unlikely	Low	Likelihood supported by stability evaluations in RWD design report. Foundation does not include permafrost overburden
2	Erosion on steeper portions of RWD leads to loss of cover and results in need for repairs	Conseq. Costs	Minor	Possible	Moderate	Can be mitigated through design and/or O&M plan
3	Die-back of cover vegetation after successful establishment and acceptance leads to erosion, and need for repair	Conseq. Costs	Minor	Possible	Moderate	RWD will have been covered/ planted for several years; appropriate selection of veg species would reduce chance of wholesale die-back. Can be mitigated through design and/or O&M plan
4	Root throw results in increased infiltration over the long term and leads to need for repair	Conseq. Costs	Minor	Unlikely	Low	Can be mitigated through design (including appropriate selection of veg species) and/or O&M plan
5	Ridgetop Waste Dump name creates perception that there will be major viewshed impacts	Comm/Media/Rep	Minor	Possible	Moderate	Could be mitigated through education and information sharing
4	**Reclamation Overburden Dump, Ridgetop South and Area 118 Backfill Dumps**					
W	Water Management					
1	Precipitation higher than expected resulting in failure of water conveyance structures because structures are underdesigned				#N/A	Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA
2	Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration, leading to ongoing maintenance costs				#N/A	Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA
3	Run-on water from upgradient catchments increases flow subsurface and contaminant loading from waste rock leading to unacceptable downstream water quality	Env. Imp.	Moderate	Very Unlikely	Low	Dump contents are overburden
4	Ponding of water on surface of overburden dumps leads to excessive infiltration, increases flow subsurface and contaminant loading from overburden leading to unacceptable downstream water quality	Env. Imp.	Moderate	Very Unlikely	Low	Designs of A118 and RS BD are mounded to shed water.

5	RS BD is not constructed to design limits, resulting in development of a pit lake within RS BD pit leading to spill of pit water and erosion of downgradient slope leading to need for development of channel	Conseq. Costs	Minor	Very Unlikely	Low	Likely will not form lake based on lack of water encountered in A118 pit. Could be mitigated by filling with waste rock during mining or by filling later with ob or waste rock
P	Physical Stability					
1	Erosion on steeper portions of dumps leads to sedimentation in conveyance channels and need for maintenance				#N/A	Scenario topic covered in #12 in 2014 FMEA
2	Die-back of vegetation after successful establishment and acceptance leads to erosion, and need for repair	Conseq. Costs	Minor	Unlikely	Low	No requirement to maintain cover integrity due to dump material (ob)
3	Storage of overburden in pits creates perception that valuable reclamation materials are being wasted	Comm/Media/Rep	Minor	Almost Certain	Moderately High	Could be mitigated through education and information sharing

	6. MAIN DAM	Consequence		Likelihood	Risk Rating	NOTES
		Type	Severity	Probability	Descriptive	
1	Blockage or settlement of Ditch 300 leads to water in Main Pit and the Main dam has settled, leading to opertopping of the Main Dam resulting in breach, release of tailings and water to lower Minto Creek	Env. Imp.	Major	Possible	High	Assumes Main Dam has settled and/or blockage of the spillway -Could be mitigated by adding material to dam to account for settlement and/or reevaluation of spillway
2	Blockage or settlement of Ditch 300 leads to water in Main Pit and the Main dam has settled, leading to opertopping of the Main Dam resulting in breach, release of tailings and water to lower Minto Creek	Comm/Media/Rep	Critical	Possible	High	Assumes Main Dam has settled and/or blockage of the spillway -Could be mitigated by adding material to dam to account for settlement and/or reevaluation of spillway -Any breach of tailings would be considered a critical severity to the local community
3	Thawing of entrained ice leads to settlement in the pit and ponding of water against the dam leading to excessive seepage and piping resulting in dam failure and release of tailings that remain within the mine site and water is released to lower Minto Creek.	Env. Imp.	Moderate	Unlikely	Moderate	Rockfill dam not likely to pipe.
4	Thawing of entrained ice leads to settlement in the pit and ponding of water against the dam leading to excessive seepage and piping resulting in dam failure and release of tailings that remain within the mine site and water is released to lower Minto Creek.	Conseq. Costs	Moderate	Unlikely	Moderate	Rockfill dam not likely to pipe.
5	Rapid/Massive failure of the Pit high wall resulting in material entering the pit and displacing tailings that remain within the pit.	Conseq. Costs	Minor	Unlikely	Low	
6	Shallow toe failure in the thawed ground leading to slumping and damage to the dam resulting in need for repair.	Conseq. Costs	Minor	Possible	Moderate	
7	Continued movement along the shear zone at the DSTSF leads to movement of the shear zone near the dam leading to cracking of the core and failure of the liner leading to breach release of tailings and water to lower Minto Creek	Env. Imp.	Major	Very Unlikely	Moderate	
8	Earthquake leads to liquefaction of foundation soils resulting in downstream slope failure resulting in a breach and release of tailings and water to lower Minto Creek	Env. Imp.			#N/A	Not rated. High level of uncertainty - needs to be investigated
9	Failure of the north wall of the Area 2 Pit leads to failure of the south abutment and progressive failure of the dam resulting in release of tailings and water to lower Minto Creek	Env. Imp.			#N/A	Not rated. High level of uncertainty - needs to be investigated

	7. DRY STACK TAILINGS STORAGE FACILITY	Consequence		Likelihood	Risk Rating	NOTES
		Type	Severity	Probability	Descriptive	
1	Long-term permafrost degradation underlying the DSTSF leads differential settlement and ponding of water resulting in increased infiltration leading to unacceptable downstream water quality	Env. Imp.	Minor	Unlikely	Low	
2	Long-term permafrost degradation underlying the DSTSF leads differential settlement and ponding of water resulting in need for repair	Conseq. Costs	Minor	Possible	Moderate	
3	Long-term permafrost degradation underlying the DSTSF leads differential settlement and ponding of water resulting in erosion of cover materials and sediment loading to passive treatment system	Env. Imp.	Minor	Possible	Moderate	Maintenance issue
4	Re-initiation of shear zone due to thawing of permafrost from the bottom up due to high excess pore pressure and movement in the cross- valley direction, leading to cracking of the cover, increased infiltration and impacts to downstream water quality.	Env. Imp.	Minor	Very Unlikely	Low	Mitigated by construction of MVFE S2
5	Deep-seated downvalley slope failure of the MVFE (Section F) leads to instability of the DSTSF and cracking of the cover, failure of conveyance ditches and need for additional stabilization measures.	Conseq. Costs	Major	Very Unlikely	Moderate	MVFE S2 design report calculates a minimum FOS of 2.3. MVFE S2 will be constructed years before closure resulting in years of performance monitoring.
6	MVFE S2 does not extend far enough downvalley to prevent cross-valley movement at the eastern extent of the current movement affecting the DSTSF.	Env. Imp.			#N/A	Not rated. To be investigated by the designer.
7	Toe failure of the MVFE (Section F) leads to instability and cracking of the cover, failure of conveyance ditches and need for additional stabilization measures.	Env. Imp.			#N/A	Not rated. To be investigated by the designer.
8	Landslide dam forms in footprint of Water Storage Pond as a result of thawing of permafrost overburden in S valley wall due to presence of Water Storage Pond leads to impounding of water and subsequent rapid breach and sediment loading downstream	Env. Imp.	Minor	Possible	Moderate	Consider including in post-closure monitoring
9	Movement (lateral movement or differential settlement) reduces or blocks flow from the finger drains underlying the DSTSF results in increased pore pressure within tailings mass, raising of water table within tailings mass and ultimately increased daylighting of groundwater upgradient of DSTSF	Env. Imp.	Minor	Very Unlikely	Low	

	10. Source Characterization and Control	Consequence		Likelihood	Risk Rating	NOTES
		Type	Severity	Probability	Descriptive	
1	Source water quality (source term) worse than predicted resulting in problematic exceedances of downstream water quality objectives	Env. Imp.	Major	Unlikely	Moderately High	Severity requires that no AMP response occurs
2	Source water quality (source term) worse than predicted resulting in problematic exceedances of downstream water quality objectives	Conseq. Costs	Critical	Unlikely	Moderately High	Assumes either active treatment or implementation of high quality covers
3	Source water quality (source term) worse than predicted resulting in problematic exceedances of downstream water quality objectives	Comm/Media/Rep	Critical	Unlikely	Moderately High	

	11. WATER TREATMENT	Consequence		Likelihood	Risk Rating	NOTES
		Type	Severity	Probability	Descriptive	
1	Passive treatment performance is not sufficient to meet downstream closure water quality objectives				#N/A	After considerable discussion, workshop concluded that the current state of information on the topic of passive treatment does not support assigning likelihood or severity ratings to scenarios around failure of passive treatment.

	12. WATER CONVEYANCE	Consequence		Likelihood	Risk Rating	NOTES
		Type	Severity	Probability	Descriptive	
T	**Tertiary Channels**					
1	Differential settlement leading to excessively concentrated flows in channels leading to erosion and filling of the energy dissipator structures	Conseq. Costs	Minor	Likely	Moderate	Assuming occurs 8 years after closure Mitigatable by performing routine O&M, encorporating rock into soil.
2	Differential settlement leading to excessively concentrated flows in channels leading to waste rock exposure and infiltration leads to unacceptable water quality downstream	Env. Imp.	Minor	Possible	Moderate	Mitigatable by performing routine O&M, encorporating rock into soil.
3	Differential settlement leading to excessively concentrated flows in channels leading to waste rock exposure and infiltration leading to repair requirements	Conseq. Costs	Minor	Likely	Moderate	Mitigatable by performing routine O&M, encorporating rock into soil.
4	Inadequate design of tertiary network results in need for repairs	Conseq. Costs	Minor	Possible	Moderate	Mitigatable by performing routine O&M, encorporating rock into soil. -Further clarification of the design event to be completed.
5	Vegetation growth is less than expected leading to concentrated flows resulting in erosion and filling of the energy dissipator structures	Conseq. Costs	Minor	Possible	Moderate	Mitigatable by performing routine O&M, encorporating rock into soil.
S	**Secondary**					
1	Excessive concentrated flows lead to erosion and gulley formation and mass wasting leading to unacceptable sediment load downstream	Env. Imp.	Minor	Possible	Moderate	
2	Excessive concentrated flows lead to erosion and gulley formation leading to waste rock exposure and infiltration leads to unacceptable water quality downstream	Env. Imp.	Minor	Possible	Moderate	
3	Excessive concentrated flows lead to erosion and gulley formation leading to repair requirements	Conseq. Costs	Minor	Possible	Moderate	
4	Inadequate design of secondary network results in need for repairs	Conseq. Costs	Minor	Possible	Moderate	-Further clarification of the design event to be completed.
P	**Primary**					
1	Instability of the MPD leads to a breach of Ditch 300 resulting in erosion of MPD waste rock cover and exposure of waste rock and infiltration leading to unacceptable water quality downstream	Env. Imp.	Minor	Unlikely	Low	
2	Instability of the MPD leads to a breach of Ditch 300 resulting in erosion of MPD waste rock cover and exposure of waste rock and infiltration leading to repair requirements	Conseq. Costs	Minor	Possible	Moderate	Assumes repair and not a wholescale repair in design
3	Inadequate design of primary network results in need for repairs	Conseq. Costs	Moderate	Unlikely	Moderate	
4	Flows exceed channel capacity resulting in failure of water conveyance structures resulting in a need for repairs	Conseq. Costs	Moderate	Unlikely	Moderate	-Further clarification of the design event to be completed.
5	SWD toe seepage collection systems inadequate, leading to unacceptable WQ downstream	Env. Imp.	Moderate	Almost Certain	High	Not part of RCP v5.1rated, subject of reclamation research; can be mitigated by inclusion
6	Extreme event leads to failure of TDD conveyance structure upgradient of DSTSF, flow onto DSTSF leading to cover damage and tailings mobilization across top of DSTSF leading to unacceptable water quality conditions downstream	Env. Imp.	Moderate	Very Unlikely	Low	Requires erosion of >3m of cover
7	Leakage from TDD conveyance structure upgradient of DSTSF increases flow subsurface and contaminant loading from tailings leading to unacceptable downstream water quality	Env. Imp.	Moderate	Unlikely	Moderate	
8	Winter ice development in primary channels results in inadequate capacity to pass freshet flows resulting in need for repairs.	Conseq. Costs	Moderate	Possible	Moderately High	May be a recuring event. Risk is lower where foundation is mine fill.

PS	**Physical Stability**					
1	Thaw degradation leading to differential settlment of spillway, distruption of the armour layer, and scour of the spillway resulting in the need for repairs	Conseq. Costs	Moderate	Possible	Moderately High	May be a recuring event. Configuation of spillway at closure needs to be considered. Consider emergency spillway during operations and different long term spillway. (consider in rock on north side). Likelyhood could be mitigated with routine maintenance.
2	Thaw degradation leads to retrogressive failure at outlet of main pit spillway resulting in the need for repairs.	Conseq. Costs	Moderate	Possible	Moderately High	same as above
3	Thaw degradation leading to differential settlement at the outlet of the Area 2 Pit resulting in the need for repairs.	Conseq. Costs	Minor	Likely	Moderate	
4	Thaw degradation leading to differential settlment in Ditch 400 downstream of the outlet leading to distruption of the armour layer, and scour of the channel resulting in the need for repairs	Conseq. Costs	Minor	Possible	Moderate	
5	Thaw degradation leading to differential settlement in Ditch 400 downstream of the outlet leading to ponding, overtopping, and erosion resulting in the need for repairs.	Conseq. Costs	Minor	Unlikely	Low	To be checked by designers
6	Thaw degradation leading to differential settlement in Ditch 400 downstream of the outlet leading to ponding, overtopping and erosion resulting in sediment loading into passive treatment system leading to impacts to water quality.	Env. Imp.	Moderate	Very Unlikely	Low	
7	Geotechnical failure of any waste facility (slope stability) resulting in debris dam, breaching, mobilizing materials and pulse of water into Main Pit, and sediments/tailings leaving pit, leading to unacceptable water quality conditions downstream of site	Env. Imp.	Very Low	Very Unlikely	Low	Revisit on Aug 28
C	**Chemical Stability**					
1	Increased infiltration through unlined Ditch 200 and Ditch 300 leads to unacceptable water quality conditions downstream of site	Env. Imp.	Moderate	Very Unlikely	Low	

	14. ADMINISTRATIVE	Consequence Type	Consequence Severity	Likelihood Probability	Risk Rating Descriptive	NOTES
1	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.) resulting in impacts on ecosystem components.	Env. Imp.	Major	Likely	High	Impacts on Minto Creek. Reason for this rating is a lack of O&M plan beyond year 13. Some uncertainty resulting from effects of permafrost degradation and climate change.
2	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.) resulting in negative traditional use	Trad. Use	Critical	Likely	Very High	-Assumes the existing traditional land use impacted due to perception; cease in trapping, hunting, berry gathering activity in area. -Assumes intended post-mining land use same as pre-mining land use
3	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.) resulting in regulatory/legal action.	Reg. & Legal	Critical	Possible	High	-Assumes company remains the responsible company.
4	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.) resulting in ….	Conseq. Costs			#N/A	Not rated. In the event that this occurs there is likely to be a large public liability
5	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.) resulting in community/media/reputation impacts	Comm/Media/Rep	Critical	Likely	Very High	media and reputation aspects of the concequence severity description were disregarded in rating.
6	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.) resulting in H&S impacts	Human H&S	Minor	Unlikely	Low	
7	Departure from design of engineered structures, resulting in unacceptable water quality conditions downstream	Env. Imp.	Moderate	Possible	Moderately High	Can be mitigated with appropriate QA/QC monitoring
8	Departure from design of engineered structures, resulting in need for upgrades/ repairs/ redesign	Conseq. Costs	Major	Possible	High	Can be mitigated with appropriate QA/QC monitoring
9	Bankruptcy/ dissolution of the company and inadequate financial security leads to requirement for public government to fund and conduct preventative mainenance and corrective actions to avoid system failures and impacts on ecosystem components.	Conseq. Costs	Major	Possible	High	Likelihood rating was selected to reflect that this scenario has happened elsewhere
10	Revegetation does not meet closure objectives relating to end land use	Trad. Use	Moderate	Possible	Moderately High	Can be mitigated through appropriate selection of end land use, determination of end land use goals, appropriate development of closure objectives to support those goals, and appropriate selection of veg species and revegetation methods
11	Failure of institutional controls resulting in land use that causes unanticipated negative exposure of humans or wildilife	Human H&S	Critical	Very Unlikely	Moderately High	Rated assuming failure results in a human fatality. Likelihood rating considers remoteness of site.
12	Failure to adequately meet reporting requirements results in noncompliance	Reg. & Legal	Minor	Possible	Moderate	

APPENDIX D

FMEA SUMMARY RESULTS

Summary of Risk Ranking for All Scenarios Considered

Likelihood	Consequence Severity				
	Very Low	**Minor**	**Moderate**	**Major**	**Critical**
Almost Certain	**3.2-W6**	**3.4-P3**	**12-P-5**		
Likely		**12-T-1, 12-T-3, 12-PS-3, 3.1-P2**		**14-1**	**14-5, 14-2**
Possible		**12-T-2, 12-T-4, 12-T-5, 12-S-1, 12-S-2, 12-S-3, 12-S-4,12-P-2, 12-PS-4, 6-6, 7-2, 7-3, 7-8, 2.2-W2, 2.3-W1, 3.1-P3, 3.2-P2, 3.2-P3, 3.2-P5, 3.3-P2, 3.3-P3, 3.3-P5, 14-12**	**12-P-8, 12-PS-1, 12-PS-2, 2.1-C3, 2.1-C4, 2.1-C7, 2.2-C2, 14-7, 14-10**	**6-1, 14-8, 14-9**	**6-2, 14-3**
Unlikely		**12-P-1, 12-PS-5, 6-5, 7-1, 2.1-W1, 2.2-W1, 3.1-P4, 3.2-P4, 3.3-P4, 3.4-P2, 14-6**	**12-P-3, 12-P-7, 12-P-4, 6-3, 6-4, 2.1-P1, 2.1-P2, 2.1-C1, 2.1-C2, 2.1-C5, 2.3-P2, 2.3-P3, 3.1-W4, 3.2-W5, 3.3-W4**	**10-1**	**10-2, 10-3**
Very Unlikely	**12-PS-7**	**12-PS-6, 7-4, 7-9, 2.2-P1, 2.3-P1, 3.4-W5**	**12-C-1, 12-P-6, 2.1-W7, 2.1-C6, 2.2-C1, 2.2-C3, 2.3-W2, 3.1-W3, 3.1-P1, 3.2-W4, 3.2-P1, 3.3-W4, 3.3-P1, 3.4-W3, 3.4-W4**	**6-7, 7-5, 2.1-W2, 2.1-W3, 2.1-W4**	**2.1-W5, 2.1-W6, 2.1-P3, 14-11**

Legend:

Descriptors: Site Area – Category – Scenario (e.g. 12-T-1). ** Some descriptors are simplified to Site Area – Scenario (e.g. 14-5)

Site Areas: 2 – Pits, 3 – Waste Rock Dumps, 6 – Main Dam, 7 – Dry Stack Tailings Storage, 10 – Source Control, 11 – Water Treatment, 12 – Water Conveyance, 14 – Administrative

Category: W – Water Management, P - Physical Stability, C - Chemical Stability, A – Administrative

Site Area 12 (Water Conveyance) is unique in its nomenclature in that it used slightly different modifiers, as follows:
P: Primary, S: Secondary, T: Tertiary and PS: Physical Stability

Scenario: Refer to Risk Scenarios in Appendix C for description of the scenarios considered.