APPENDIX C

MINTO CLOSURE PRELIMINARY FAILURE MODES AND EFFECTS ASSESSMENT - RISK REGISTER

	Closure Scenario 1: Source Control Focus	Consequence		Likelihood	Risk Rating	NOTES
		Type	Severity	Probability	Descriptive	
1	**Source Terms**					
A	Source water quality (source term) worse than expected and causes unacceptable water quality conditions **downstream of site**	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		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	
H	Precipitation higher than expected resulting in failure of water conveyance structures because structures are underdesigned	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	Env. Imp.	Minor	Likely	Moderate	
2	**Cover Performance**					
A	Covers don't perform as designed re: infiltration resulting in unacceptable water quality conditions **downstream of site**	Env. Imp.	Moderate	Unlikely	Moderate	Assuming AMP and monitoring will respond to any defects
B		Conseq. Costs	Major	Unlikely	Moderately High	
3	**Geotechnical 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	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	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	Env. Imp.	Minor	Possible	Moderate	
4	**Conveyance Structures**					
A	Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration, leading to ongoing maintenance costs	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	Env. Imp.	Moderate	Unlikely	Moderate	
5	**Administrative**					
A	Failure to implement AMP, resulting in unacceptable water quality conditions downstream	Env. Imp.	Critical	Possible	High	
B	Failure to design an appropriate AMP, resulting in unacceptable water quality conditions downstream	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	Env. Imp.	Major	Possible	High	

	Scenario 2: Hybrid Source Control/Passive Treatment Focus	Consequence		Likelihood	Risk Rating	NOTES
		Type	Severity	Probability	Descriptive	
1	**Bioreactors**					
A	Bioreactors don't perform as designed - overwhelmed, freeze, resulting in unacceptable water quality conditions downstream	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.
2	**Wetlands**					
A	Wetlands don't perform as designed - overwhelmed, freeze, resulting in unacceptable water quality conditions downstream	Env. Imp.	Moderate	Almost Certain	High	
B	High flow blow out wetland, causing damage and maintenance requirements, assuming high flows designed to bypass	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.
3	**Pit Lake Treatment**					
A	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	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	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	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.
4	**Cover Performance**					
A	Does not achieved expected infiltration reduction, leads to increased loading and unacceptable downstream WQ effects	Env. Imp.	Moderate	Possible	Moderately High	
B	Erosion leads to increased infiltration and unacceptable downstream WQ effects	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.
5	**Conveyance Structures**					
A	Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration, leading to ongoing maintenance costs	Conseq. Costs	Minor	Unlikely	Low	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	Env. Imp.	Moderate	Possible	Moderately High	
6	**Administrative**					
A	General failure to maintain site requirements as required - passive treatment, cover maintenance, etc.	Env. Imp.	Major	Possible	High	

	Scenario 3: Treatment Focus	Consequence		Likelihood	Risk Rating	NOTES
		Type	Severity	Probability	Descriptive	
	Assumption is that this option needs redesign compared with existing collection/treatment system in place - many risks could be addressed through this redesign, or batch treatment, etc.					
1	**Collection Systems**					
A	Tailings seepage collection systems inadequate, leading to unacceptable WQ downstream	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	SWD toe seepage collection systems inadequate, leading to unacceptable WQ downstream	Env. Imp.	Minor	Likely	Moderate	minor because pit is downstream
D		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 in inadequate, leading to mixing with water requiring treatment and increased treatment costs	Conseq. Costs	Minor	Likely	Moderate	
2	**Cover Performance**					
A	Does not achieved expected infiltration reduction, leads to increased loading and unacceptable downstream WQ effects	Env. Imp.	Moderate	Possible	Moderately High	Assumption that these Option 3 covers are thinner than Option 2
B	Erosion leads to increased infiltration and unacceptable downstream WQ effects	Env. Imp.	Moderate	Possible	Moderately High	risks different for DSTSF than for other facilities, potential effects of erosion still need to be considered in design, maintenance costing, etc.
C	Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration, leading to ongoing maintenance costs	Conseq. Costs	Moderate	Unlikely	Moderate	Need to do landscape design carefully to avoid this failure mode
D	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	Env. Imp.	Moderate	Possible	Moderately High	
3	**Dam - assume reduced height**					**may want to consider removing top level at least - man/made materials**
A	Seismic or extreme flood event larger than design leads to dam failure, resulting in surge of water and solids into Minto Creek	Env. Imp.	Moderate	Very Unlikely	Low	
B	Dam 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
4	**Treatment Plant (plant, any byproduct, and storage capacity)**	**Env. Imp.**	**Very Low**	**Very Unlikely**	**Low**	
A	Flow rates exceed plant/surge capacity, resulting in unnacceptable water quality downstream	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 unnacceptable water quality downstream	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 unnacceptable water quality downstream	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	
5	**Administrative**	**Env. Imp.**	**Very Low**	**Very Unlikely**	**Low**	
A	General failure to maintain site requirements as required - collection/conveyance, active treatment, cover maintenance, etc.	Env. Imp.	Major	Possible	High	