Appendix B
SFN Stakeholder & Regulator Engagement Table

Date, Event, Location	Stakeholder/Group	Issue	Engagement Details	Outcome/Purpose
2011				
05/05/2011 (Meeting) Whitehorse	Selkirk Development Corporation (SDC).	Contacts, roles and responsibilities	A discussion was held with members of SDC to provide updates on contacts within SFN and Minto.	Clarification of roles and responsibilities, exchange of contact information, areas identified for future collaboration.
27/05/2011 (Meeting) Whitehorse	Minto technical working group	Mine updates, review of current technical plans, indications for future plans given	This working group intended as a forum for input into conceptual technical plans from wide regulator/stakeholder group (YG, federal government, NGOs, etc.)	Information exchanged, input gathered on technical issues, plans for future licensing / permitting provided.
12/06/2011 (Meeting) Whitehorse	Minto Landing working group	Various technical and legal issues	Discussion between Minto on-site staff and SFN Lands department representatives regarding operation of the mine.	Communication intended to ensure up-to-date information being shared on daily activities at site.
16/06/2011 (Meeting) Whitehorse	BTWG	Geotechnical issues at Minto	Minto technical team prepared presentation to respond to questions from SFN's technical reviewers, mostly related to geotechnical issues related to Mill Valley Fill (MVF).	Discussion regarding various geotechnical aspects of mine facilities. Suggestions were made, recorded and plans made for further discussion in July/August.
30/06/2011 (Meeting) Pelly Crossing	Minto Landing working group	Various technical and legal issues	Discussion between Minto on-site staff and SFN Lands department representatives regarding operation of the mine.	Communication intended to ensure up-to-date information being shared on daily activities at site.
19/07/2011 (Meeting) Whitehorse	BWTG	Geotechnical issues at Minto	Geotechnical and water licence concerns, mostly related to MVF.	Discussion and information exchange related to issues, input gathered and plans made for future discussions.
17/08/2011 (Meeting) Pelly Crossing	Chief and Council	General updates	Regular meeting between respective leaderships.	Sharing of information in accordance with co-op agreement.
20/08/2011 (Presentation) Pelly Crossing	Community	General Assembly (GA) presentation	Minto representatives were given the opportunity to make a presentation to the entire SFN community as part of their annual GA.	Presentation by Minto employees on mine operations, future plans and question/answer period.
28/08/2011		Site tour		Sharing of information with community leaders.

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(Site Tour) Minto	Selkirk renewable resource council (SRRC)		Representatives from the SRRC spent the day on site touring and partaking in dialogue with senior staff members who answered questions and provided demonstrations.	
31/08/2011 (Meeting) Minto	Minto technical working group	Mine updates, review of current technical plans, indications for future plans given	This meeting was held at site in order to provide context for members of the group who aren't familiar with site.	Field review of issues discussed during previous meeting.
01/09/2011 (Meeting) Whitehorse	Tri-partite working group	Initial discussions to begin work of this group (YG, Minto and SFN)	A discussion was held to clarify roles and responsibilities within this group.	Clarifications made, plans for future discussion made.
16/09/2011 (Meeting) Whitehorse	Minto technical working group	Discussion of permitting issues and technical work plans at Minto	This meeting was help in follow up to a proposed tour which many invitees could not attend. The discussion included updates on Minto activities and technical presentations by Minto's team on geotechnical matters affecting the mine including wall stability and dry stack tailings.	Provided responses to many technical questions, received input on plans, issues.
29/09/2011 (Meeting) Whitehorse	Various government agencies	Discussion of permitting issues and upcoming water licensing application	This meeting was held to discuss the role of Yukon government in the upcoming licensing process and provide insights into the scope of amendments being requested by Minto.	Clarification of roles, information sharing with government agencies.
03/10/2011 (Meeting) Pelly Crossing	Selkirk Chief and Council	General updates	Regular meeting between respective leaderships.	Sharing of information in accordance with co-op agreement.
04/10/2011 (Meeting) Whitehorse	Tri-partite working group meeting	Minto socio-economic effects monitoring	Collaboration with SFN and YG on how to meet requirements from Phase IV decision document re: socio-economic effects monitoring, as well as Minto's requirement to put forward socio-economic assessment for next YESAB application.	Clarified roles and responsibilities and discussed scope of effects monitoring, information resources, confidentiality, methods for collection of information, expected outcomes, etc.
14/10/2011 (Meeting) Whitehorse	Tri-partite working group follow up discussion	Socio-economic effects monitoring	Discussion with SFN team member on Tri-partite action items and follow up.	Meeting commitments for information sharing and planning next steps.
20/10/2011				

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(Meeting) Whitehorse	Bi-lateral working group and Minto Landing working group	Operational updates, information on the preparation of upcoming water licence amendment	Water and waste management and Minto – current and future in the context of amendment #7 reasons for decision (issued in October 2011).	Sharing of views on Water Board RFD and discussion of how to proceed on water and waste management practices.
25/10/2011 (Meeting) Whitehorse	Tri-partite working group meeting	Socio-economic effects monitoring	Discussion with working group.	Discussion on progress to date.
28/10/2011 (Meeting) Whitehorse	Bi-lateral working group meeting	Water Licence amendment #8 review with SFN	Discussion with technical team and community members.	Information sharing, receiving input for inclusion in Minto plans, answering questions from community members and technical team. Discussion extended to closure and reclamation issues.
04/11/2011 (Meeting) Pelly Crossing	SFN social programs coordinator	Minto participation/funding social programs	Discussion to understand how Minto can meet commitments to social well-being and ideas for the holidays.	Information sharing, ideas for Minto's involvement based on needs in the community.
07/11/2011 (Meeting) Pelly Crossing	Selkirk Development Corp. leadership	Current and future business opportunities	Minto site updates regarding contracts and discussion of upcoming opportunities.	Information sharing, updates on contact information.
14/12/2011 (Meeting) Pelly Crossing	Selkirk Chief and Council	General updates	Regular meeting between respective leaderships.	Sharing of information in accordance with Co Op Agreement.
2012				
23/01/2012 (Meeting) Pelly Crossing	Selkirk Development Corp. leadership	Current and future business opportunities	Minto site updates regarding contracts and discussion of upcoming opportunities.	Information sharing, updates on contact information.
03/02/2012 (Meeting) Whitehorse	Bi-lateral working group meeting	Ongoing water licensing issues	Water management issues related to Mill Valley Fill; discussed Minto response to water licence information request.	Information sharing, receiving input for inclusion in Minto plans, answering questions on Minto technical documents/submissions to Water Board. Discussion extended to closure and reclamation issues.
13/02/2012	Bi-lateral working group meeting			

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(Meeting) Whitehorse		Water licence amendments and closure	Updates on Minto progress related to water licensing.	Input received, information shared, plans made for future engagement.
07/03/2012 (Meeting) Pelly Crossing	SFN employment liaison	Welcome meeting	Employment of SFN members at Minto mine.	Information sharing and action items related to increased hiring of SFN members at Minto Mine.
21/03/2012 (Site Tour) Minto	Community	Site tour	Open invite to community members to tour the site.	Information sharing, relationship building.
23/03/2012 (Meeting) Pelly Crossing	Bi-lateral working group	Water Licensing and upcoming YESAB submission	Water and waste management, response to information requests from the water board. Took questions from community on various Minto issues.	Information sharing, receiving input for inclusion in Minto plans, answering questions on Minto technical documents/submissions to Water Board.
03/04/2012 (Presentation) Pelly Crossing	Community	Employment	SFN Community hosted Minto representatives for a job fair style event. Presentations made providing more information on careers at Minto Mine.	Contacts made, information shared, questions answered.
24/04/2012 (Meeting) Whitehorse	Bi-lateral working group	Water licensing and upcoming YESAB assessment application	Water and waste management issues, information requests related to water licence amendment #8.	Ongoing updates provided, information shared, plans for future engagement made.
24/05/2012 (Meeting) Whitehorse	Bi-lateral working group	Water licensing and upcoming YESAB assessment application	Water and waste management issues, information requests related to water licence amendment #8.	Ongoing updates provided, information shared, plans for future engagement made.
31/05/2012 (Meeting) Pelly Crossing	SFN citizens	Socio-economic study	Two community meetings in Pelly Crossing (afternoon and evening). Over 20 community members attended the afternoon meeting and 10 attended the evening meeting.	Discuss and identify socio-economic values and potential effects.
07/06/2012 (Meeting) Pelly Crossing	Bi-lateral working group	Water licensing, upcoming amendment #8 hearing review	Water and waste management issues, information requests related to water licence amendment #8.	Ongoing updates provided, information shared, plans for future engagement made.

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14/06/2012 (Meeting) Whitehorse	Minto technical working group	Water licence upcoming hearing related to amendment #8	Meeting with wide reviewer audience to explain technical information that will be discussed at upcoming water licence amendment hearing.	Minto updates provided, review of technical information submitted to Water Board.
15/06/2012 (Meeting) Whitehorse	Bi-lateral working group	Water licensing, upcoming amendment #8 hearing review	Water and waste management issues, information requests related to water licence amendment #8.	Ongoing updates provided, information shared, plans for future engagement made.
18/07/2012 (Site Visit) Minto Mine	Regulator	Closure	Site tour with YG, Energy, Mines, and Resources representatives.	Orientation to mine site and discussion of closure.
09/08/2012 (Newsletter) Pelly Crossing	SFN citizens	Socio-economic study	Newsletter sent to all SFN citizens and community members in Pelly Crossing.	Newsletter provided information on socio-economic data gathering and project activities.
14/08/2012 (Meeting) Pelly Crossing	SFN citizens	Socio-economic study	Community meeting facilitated by Klohn Crippen with participation of Minto representatives.	Informal discussion, with Power Point presentation, to discuss socio-economic values and potential effects as they relate to Phase V/VI.
2012/08/14-17 (Interviews) Pelly Crossing	SFN citizens/ community members	Socio-economic study	Thirteen individual interviews with community members and individuals working in the community.	Socio-economic data collection.
15/08/2012 (Presentation) Pelly Crossing	SFN Elders' Council	Socio-economic study	Presentation to Elders' Council (23 Elders and 1 SFN Coordinator).	Informal discussion, with PowerPoint presentation, to discuss socio-economic values and potential effects as they relate to Phase V/VI.
15/08/2012 (Meeting) Whitehorse	BTWG	Various technical issues	All-day meeting with approximately 5 technical representatives from each of Minto and SFN.	Structured technical discussions regarding: closure, permit applications (Phase V/VI), site activities, and status.
15/08/2012 (Meeting)	SFN Socio-economic working group representatives	Socio-economic study	Meeting (informal dinner) between Klohn Crippen and SFN socio-economic working group representatives.	Discussion of comments received from Socio-economic Tri-partite Working Group.

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Whitehorse				
23/08/2012 (Telephone Interview)	SFN citizens/ community members	Socio-economic study	Individual interview with one community member.	Socio-economic data collection.
28/09/2012 (Letter)	Chief McGinty	Phase V/VI	Letter sent to Chief McGinty.	Written request to discuss details of Phase V/VI with Chief and Council as well as with the community.
16/10/2012 (Meeting) Pelly Crossing	SFN citizens	Introduction to Phase V/VI	Afternoon and evening meeting (with dinner) for SFN citizens and community members. Approximately 40 people attended. Translator (Northern Tutchone) provided.	Informal discussion, with PowerPoint presentation and maps, of activities to be undertaken for Minto Phase V/VI expansion. General Q&A.
16/10/2012 (Interviews) Pelly Crossing	SFN citizens/ community members	Socio-economic study	Two individual interviews with community members and individuals working in the community.	Socio-economic data collection.
2012/10/22-26 (Interviews) Pelly Crossing	SFN citizens/ community members	Socio-economic study	Sixteen individual interviews with SFN citizens and community members.	Gathering feedback on identified socio-economic values.
22/10/2012 (Meeting) Pelly Crossing	Klohn Crippen and SFN's socio-economic working group representatives	Socio-economic monitoring program	Meeting with Klohn Crippen and SFN SE working group representatives.	Discussion of socio-economic baseline data being collected by Klohn Crippen.
29/10/2012 (Meeting) Pelly Crossing	Chief and Council	Various	Attended SFN Chief and Council meeting.	Discussed BTWG, mine tours, socio-economic work, consultation, river crossing, water quality monitoring proposal, training opportunities for employees.
2012/10 (Newsletter)	SFN citizens/ community members	General mine information and Phase V/VI information	Newsletter sent to all SFN citizens and community members.	Information provided on mine team, jobs, training, Phase V/VI, opportunities for feedback.
2012/10 (Newsletter)	SFN citizens/ community members	Socio-economic study newsletter	Newsletter sent to all SFN citizens and community members.	Provided a summary of study activities and a questionnaire on valued socio-economic components.
01/11/2012 (Meeting)	EMR and SFN	Closure	Meeting with YG Energy, Mines and Resources and SFN.	Closure cost update for Phase IV.

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Whitehorse				
08/11/2012 (Meeting) Whitehorse	BTWG	Waste management	Approximately a half dozen technical representatives from each of Minto and SFN.	Members from both Minto's and SFN's technical teams met to discuss the creation of technical working groups as well as Minto providing an overview of Phase V/VI.
09/11/2012 (Call)	SFN technical consultant(s)	Closure	Call between Minto and SFN technical consultants.	Discussions about planning process, MAA and FMEA for closure.
14/11/2012 (Call)	SFN technical consultant(s)	Closure	Call between Minto and SFN technical consultants.	Discussion about closure planning process.
15/11/2012 (Call)	SFN technical consultant(s)	Waste management and closure planning	Call between Minto and SFN technical consultants.	Discussions about waste management and closure planning.
16/11/2012 (Call)	SFN technical consultant(s)	Phase V/VI	Call between Minto and SFN technical consultants.	Discussion about Phase V/VI, 2012 hydrological program, potential waste disposal options.
20/11/2012 (Presentation) Whitehorse	Public	Minto Mine	Presentation at Yukon geoscience forum.	Provided information regarding Minto Mine operations and plans.
20/11/2012 (Call)	SFN technical consultant(s)	Waste management	Call between Minto and SFN technical consultants.	Alternatives assessment process, waste rock management.
2012/11/26-28 (Mine Tour) British Columbia	SFN Elders and leadership	Closure	Minto and technical representatives, along with SFN Leadership and Lands department representatives visited Highland Valley Copper Mine.	Focus of the mine tour was on closure; successes and challenge of both standard and innovative measures.
29/11/2012 (Meeting) Whitehorse	Regulators, SFN	Introduction to Phase V/VI	Half day meeting with various federal and territorial regulators including: EMR, Water Board, SFN, YESAB, Environment Canada, YG Water Resources.	Informal discussion, with PowerPoint presentation, of activities to be undertaken for Minto Phase V/VI expansion. General Q&A.
03/12/2012 (Call)	SFN technical consultant(s)	Waste management	Call between Minto and SFN technical consultants.	Alternatives assessment process, Phase V/VI, water management.
09/12/2012	SFN technical consultant(s)	Phase V/VI		

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(Call)			Call between Minto and SFN technical consultants.	Review of BTWG meeting outcomes, closure planning.
11/12/2012 (Meeting) Whitehorse	EMR and SFN	Closure	Meeting with YG Energy, Mines and Resources and SFN.	Review of new draft ERM reclamation closure plan guidelines.
13/12/2012 (Workshop) Whitehorse	BTWG	Waste management alternatives assessment	One-day workshop. Approximately 8 representatives from each of SFN and Minto.	Identification of preferred waste management option.
18/12/2012 (Meeting) Whitehorse	SFN leadership representatives	Consultation and community engagement	Meeting with Capstone leadership and SFN leadership representatives.	Discussion of long-term scheduling and Leadership expectations regarding community engagement.
19/12/2012 (Call)	YESAB	Update	Call with Katrine Frese (Mayo DO) and Bengt Pettersson (Exec Director) from YESAB with Minto representatives.	Overview/history of project and upcoming proposal for Phase V/VI.
2013				
26/01/2013 (Meeting) Whitehorse	SFN citizens	Introduction to Phase V/VI	Public meeting for SFN citizens living in Whitehorse (approximately 6 SFN citizens attended).	Informal discussion, with PowerPoint presentation and maps, of activities to be undertaken for Minto Phase V/VI expansion. General Q&A.
08/02/2013 (Call)	SFN's socio-economic representatives	Traditional knowledge and socio-economics	Call with Minto representatives and Klohn Crippen with SFN's socio-economic working group representatives.	Status and progress update, Q&A, traditional knowledge, socio-economic study.
12/02/2013 (Call)	SFN technical consultant(s)	Closure	Call between Minto and SFN technical consultants.	FMEA roll-up, closure planning.
18/02/2013 (Site Visit) Minto Mine	YESAB	Orientation	Site tour with YESAB Executive Director, Mayo DO Assessment Officer and DO Support.	Tour of the mine site.
19/02/2013 Call	SFN leadership representative	Water Board filings and technical details	Call between Capstone Leadership and SFN Leadership rep.	Discussion of technical issues, level of detail for WB filings.

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10/03/2013 Call	SFN leadership representative	Closure	Call between Capstone Leadership and SFN Leadership rep.	Discussion regarding closure bonding.
14/03/2013 (Site Visit) Minto Mine	YESAB	Orientation	Site tour with Mayo DO Manager and Teslin DO Manager.	Tour of the mine site.
22/03/2013 (Meeting) Whitehorse	Tri-partite working group	Socio-economic effects monitoring	Meeting of the socio-economic Tri-partite working group (Minto, SFN representatives and YG).	Discuss components of a socio-economic monitoring program.
25/03/2013 (Call)	SFN Socio-economic representatives	Socio-economic baseline report	Call with Minto and rep, SFN representatives, and Klohn Crippen.	Provide comments and feedback on the draft socio-economic baseline report.
05/04/2013 (Open House) Pelly Crossing	SFN citizens and community members	Employment opportunities	Presentation at an Open House in the Lync Building.	Presentation regarding training and employment opportunities.
04/04/2013 (Call)	SFN leadership representative	YESAA application	Call between Capstone Leadership and SFN leadership rep.	Discussion about project proposal and potential meeting with Chief and Council.
25/04/2013 (Meeting) Whitehorse	Tri-partite working group	Socio-economic effects monitoring	Meeting of the socio-economic Tri-partite working group (SFN, Minto, and YG).	Discus components of a socio-economic monitoring program.
30/04/2013 (Meeting) Whitehorse	BTWG	Phase V/VI Project	Meeting of the Bi-lateral working group (SFN, Minto) and technical representatives.	Discuss various components of the Phase V/VI project and the project proposal.
24/06/2013 (meeting) Whitehorse	YWB	Lessons learned from phase IV amendment process	Meeting between permitting manager and YWB secretariat to discuss lessons to be learned from the previous water licensing process.	
2013/08/08 (site tour) Minto Mine	YWB	Site tour for YWB Board members and staff	Tour for Board members and YWB staff to familiarize themselves with the project.	Presentations and field visit

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13/09/2013 (meeting) Whitehorse	EMR	Phase IV RCP review process and status of phase V/VI proposal	Discussion with EMR staff on the process for reviewing the phase IV RCP. Minto concerned about significant overlap between EMR process and YWB process. Discussion about timelines of YESAB process and preparation of licence applications. Minto concerned about impact from W2 water standards.	Minto to explore options for conducting some of phase V/VI work prior to receiving a water licences,
10/10/2013 (meeting) Whitehorse	YESAB	Clarification on information request	Minto required clarification on three questions in information request (B).	Clarification received
17/10/2013 (meeting) Whitehorse	SFN leadership	Principals meeting between Minto and Selkirk	Discussion between Selkirk Chief and council and Minto senior management including water quality objectives at closure	Commitment to develop WQO collaboratively.
23/10/2013 (meeting) Whitehorse	EMR	Permitting process update and QML application logistics	Minto provided status update on YESAB process and application development. Discussion on format of QML application.	
28/10/2013 (meeting) Vancouver	BTWG	Water quality objectives	Technical discussion on post closure water quality objectives.	
31/10/2013 (meeting) Whitehorse	EMR	Follow up meeting to 2013/10/23 meeting on application logistics	Staff level discussion on details of application format.	
06/11/2013 (Community	SFN citizens	Community meeting to update SFN members about	Presentations, question and answer session, discussion on various topics including scope of phase V/VI proposal and water quality	Information meeting

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meeting) Pelly Crossing		Minto Mine, including permitting and closure planning	objectives at closure.	
25/11/2013 (meeting)	YESAB	Clarification remainder of YESAB process and White River First Nation participation	Discussion on remaining steps in YESAB process and related information needs. YESAB provided clarification on how White River First Nation claims will be incorporated into the process.	
28/11/2013 (meeting) Whitehorse	EMR	Closure cost discussion	Discussion between Minto, EMR and respective consultants on closure cost estimates in relation to the phase IV RCP and the resulting security bond.	Minto to revise cost estimates following input from EMR
2014				
13/01/2014 (meeting) Whitehorse	YWB	Clarification on guidance document	Discussion to obtain clarity on information requirements under YWB's various guidance documents.	
2014/02/07 (call) Whitehorse/ Vancouver	EMR	Legal questions around YESAB process	Discussion on definition of a Decision Body under YESAA and related mandate questions.	Increased clarity on decision bodies.
13/02/2014 (meeting) Whitehorse	YESAB	Main Dam and RCP information requirements	Discussion on the information requirements for the Main Dam design and the closure plan; where does environmental assessment end and water licensing begin?	Increased clarity on the process, what information is needed and what information can re reasonably provided.
14/02/2014 (meeting)	BTWG	Water Quality Objectives	Full day workshop on water quality objectives during operations and post closure. In depth discussion on methods to derive objectives, the application of objectives, and the feasibility of achieving certain	Agreement on possible approach to setting water quality objectives.

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Whitehorse			objectives	
10/03/2014 (meeting) Whitehorse	EMR	Phase IV closure costing	Follow up discussions from 2013/11/28 to further refine closure cost estimates and resulting security bond	
30/04/2014 (meeting) Whitehorse	YWB	Licence renewal issues	Discussion to clarify the requirements and the limitations of water licence renewal application if renewal and phase V/VI are to be combined in one process.	Increased process clarity.
02/05/2014 (meeting) Whitehorse	EMR	Evaluation Report	Discussion on how to interpret conditions in the YESAB evaluation report and how they may be translated into conditions in a decision document	Minto concerned about the nature and timing of many of the conditions. Some raise mandates issues, e.g. can YESAB create a de-facto veto right for a stakeholder?
13/06/2014 (meeting) Whitehorse	BTWG	Decision Document and water quality objectives	Discussion on timing of licence applications. Discussion on Decision Document and resulting licence application requirements.	Agreement on a tentative approach for reaching consensus on as many items as possible prior to water board hearings.
20/06/2014 (meeting) Whitehorse	BTWG	Water quality objectives	In depth discussion of water quality objectives and approach to determining them. .	Agreement on general approach, further work required on defining contaminants of concern.
09/07/2014 (Meeting) Minto	SFN Leadership	Phase V/VI	Site tour and discussion regarding Phase V/VI	Concerns from SFN shared with Minto
14/07/2014 (Meeting)	BTWG	Phase V/VI	COPC selection criteria, proposed WQOs, proposed effluent quality limits and revised predictions	

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Whitehorse				
16/07/2014 (Meeting) Pelly Crossing	SFN Leadership	Chief and Council Meeting	Regular Minto and Chief and Council Meetings	
18/07/2014 (Meeting) Pelly Crossing	Yukon Government, Environment Canada, SFN	Ground Water Modeling Workshop	Ground Water Modeling Workshop	
21/07/2014 (Meeting) Whitehorse	Tripartite	Project plan and desired critical path	Project scope, process, mine development options, preview licence application	
29/07/2014 (Meeting) Whitehorse	Regulators, SFN	Stakeholder Engagement	To facilitate stockholders' upcoming review of Minto's Phase V/VI licence applications	
22/08/2014 (Meeting) Whitehorse	EMR and YWB	Licence application	To facilitate stockholders' upcoming review of Minto's Phase V/VI licence applications	
31/07/2014 (Meeting) Whitehorse	Regulators, SFN	Stakeholder Engagement	To facilitate stockholders' upcoming review of Minto's Phase V/VI licence applications	
16/09/2014 (Meeting) Whitehorse	SFN	Water quality objectives	Discussions regarding water quality objectives for the Phase V/VI applications	
18/09/2014 (Meeting) Whitehorse	EMR	General Updates	Discussing operational updates	
18/09/2014	SFN	3rd party geotechnical review	Discussing results of the geotechnical review	

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(Meeting) Whitehorse				
08/10/2014 (Meeting) Minto	SFN, EMR	Site Visit	Closure planning site visit	
11/11/2014 (Meeting) Whitehorse	SFN, EMR	Closure Planning	Discussing the details of the submitted closure plan	
2015				
08/01/2015 (Meeting) Whitehorse	BTWG	Water Quality Objectives	Discussions regarding water quality objectives for the Phase V/VI applications	
20/08/2015 (Meeting) Whitehorse	BTWG	Reset Meeting	Discussion around engagement opportunities for SFN regarding the RCP	Agreed to focus on the main points such as closure WQO, design criteria and closure objectives
10/09/2015 (Meeting) Minto	Yukon Government	Site Tour	Site tour for Yukon Environment personnel.	
15/09/2015 (Meeting) Minto	BTWG	Site Tour	Site tour for SFN technical staff.	Discussion regarding closure engagement opportunities and applying for the extension
05/11/2015 (Meeting) Phone	BTWG	Water quality objectives	WQO framework discussion with side discussion regarding AMP, Cu Toxicity Testing and Water Management review and approval process	Beginning of discussions on the WQO framework for the closure plan.
06/11/2015 (Meeting)	BTWG	Water quality objectives	WQO framework discussion with side discussion regarding AMP, Cu Toxicity Testing	Beginning of discussions on the WQO framework for the closure plan.

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Phone			and Water Management review and approval process	
16/11/2015 (Meeting) Whitehorse	Tripartite	Extension request	Discuss regarding the scope of the upcoming RCP and the proposed extension request.	EMR and SFN to support the extension request.
11/12/2015 (Meeting) Whitehorse	BTWG	Water Quality Objectives	Discussion regarding the COPC, background data set, mock WQO using the formula in the WUL. Discussion regarding attainment.	SFN to provide an attainment document and justification for inclusion of hardness in the WQO.
2016				
11/01/2016 (Meeting) Phone	BTWG	Primary Water Conveyance	Discussion regarding primary water conveyance alignments and options as well as design criteria and potential locations for wetlands	General agreement on water conveyance alignment.
23/02/2016 (Meeting) Phone	SFN Leadership	Chief and Council Meeting	General site update	
01/03/2016 (Meeting) Whitehorse	BTWG	Wetland Options	Discussions regarding different wetland configurations and options. Execution strategy.	SFN would like to see a predictable system.
05/04/2016 (Meeting) Phone	BTWG	Closure Conveyance Routing	Discussed the impact of routing water through the Area 2 Pit vs routing around Area 2 pit on the downstream hydrology. This was to address concerns raised previously by SFN.	It was agreed that there is little difference between routing on the downstream hydrology. SFN raised another concern on if area derived dilutions ratios are appropriate.
03/05/2016 (Meeting) Phone	BTWG	Wetland Concept	Discussions regarding wetland concept for WSP area and water conveyance in the area	Overall consensus on the wetland configuration
11/05/2016 (Meeting) Whitehorse	Tripartite	RCP Progress Update, Environment Audit	General RCP progress update and discussions regarding the environment audit proposal.	SFN will not support SRK carrying out the audit.

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19/05/2016 (Meeting) Phone	BTWG	Water Quality Objectives	Discussions regarding the final step of the WQO framework and how to move forward	Decision to get together and work through how to use the background water quality dataset.
02/06/2016 (Meeting) Vancouver	BTWG	Water Quality Objectives	Worked through how to use the background water quality dataset.	An agreed upon process for determining background water, water quality dataset.
14/06/2016 (Meeting) Pelly Crossing	SFN	SFN Engagement	Discussions around SFN engagement on multiple plans and programs including the RCP, Vegetation Metal Uptake Program and Environmental Audit.	General update
29/06/2016 (Meeting) Whitehorse	YWB	EMSRP and MVFES2 information request clarification	Discussed technical details regarding the MVFES2 Expected Performance and Evaluation Criteria Report and EMSRP.	Clarification received
06/07/2016 (Meeting) Minto	Tripartite	Closure concepts	Tour for EMR, YG Env. and SFN	For parties to site and advancement of operations
13/07/2016 (Meeting) Phone	BTWG	EMSRP and Groundwater Monitoring Plan	Discussion regarding the location of proposed wells. Discussed options and preferred conceptual plan for the lysimeters.	Overall general agreement with proposed well locations. General consensus on developing lysimeters that could be used to test closure cover performance.
14/07/2016 (Meeting) Phone	BTWG	Vegetation Metal Uptake Program	SFN technical advisor provided feedback on the acceptance of the proposed vegetation species to be used in the sampling program.	SFN technical advisor agreed to the proposed approach submitted to SFN for consideration.
15/07/2016 (Meeting) Phone	BTWG	W2 Background water quality determination approach	Reviewed the work by Minnow with SFN technical advisors regarding the development of the background water quality approach.	General consensus that the approach acceptable.
9/09/2016 (Meeting)	BTWG	Advancement of closure WQO development	Comparison of proposed WQO to WQ prediction.	SFN technical team to discuss with SFN leadership.

Date, Event, Location	Stakeholder/Group	Issue	Engagement Details	Outcome/Purpose
Whitehorse				
4/10/2016 (Meeting) Whitehorse	YG	Closure costing site tour	General site tour with a focus on reclamation closure measures	
3/11/2016 (Meeting) Whitehorse	BTWG	Discussions regarding closure water quality objectives.	Agreement on numerical closure WQO non degradation and 50% of assimilative capacity/ closure monitoring frequency and closure AMP also discussed	Agreement on numerical values but work remains on attainment criteria and closure AMP.
24/11/2016 (Meeting) Whitehorse	Tripartite	SFN and EMR RCP Assessment determination and Area 2 Stage 3 pit concerns	Discussed EMRs and SFNs assessment determination regarding the RCP application to the YWB. Also discussed SFN technical review comments regarding the Area 2 Stage 3 pit Mine Development and Operation Pit	Provide stability of new MPD design, water balance for Area 2 Pit a figure showing SAT dump.
5/12/2016 (Meeting) Phone	BTWG	Minto response to YWB IR	Discussion regarding the Minto's planned response to the YWB information request.	
9/12/2016 (Meeting) Pelly Crossing	SFN Leadership	Principals Meeting	General site update	
13/12/2016 (Meeting) Whitehorse	YG	YG AMP Review comments	Discussed YG AMP review comments and Minto concerns with those requests.	Minto clarified issued already addressed.
15/12/2016 (Meeting) Phone	BTWG	Closure WQO attainment criteria and Closure AMP	Discussed how closure WQO would be applied and how it would work within the Closure AMP.	No agreement was reached on the final WQO attainment or details of Closure AMP. Minto considered making some changes to the Closure AMP.

Date, Event, Location	Stakeholder/Group	Issue	Engagement Details	Outcome/Purpose
2017				
27/02/2017 (Emails) Emails	BTWG	Review of closure WQO section in the RCP	Review of closure WQO section in the RCP and looking for SFN feedback.	Feedback received from SFN technical consultants agreeing with the content of the information.
8/03/2017 (Meeting) Pelly Crossing	Pelly Community Members	General update	Review of 2017 mine plan, results of 2016, employment opportunities, RCP overview.	Questions period – Jobs, business opportunity, closure questions.
27/04/2017 (Meeting) Whitehorse	BTWG	Closure of Minto Waste Rock Dumps	Engagement and getting feedback on the implementation of progressive reclamation	SFN technical group provided feedback in person only and did not follow up with written comments
23/05/2017 (Meeting) Whitehorse	YG	RCP Costing review	Discussion regarding YG consultant costing review.	
10/07/2017 (Tour) Minto Mine	SFN Leadership	General site tour	Site tour with a focus on progressive reclamation	
13/07/2017 (Meeting) Pelly Crossing	SFN Leadership	Principals meeting	General site update	
18/07/2017 (Meeting) Whitehorse	YWB	YWB licence amendment	Discussed process for submitting the YWB licence amendment	
10/10/2017 (Tour) Minto Site	YG and YWB	General site tour	Discussion regarding groundwater.	

Date, Event, Location	Stakeholder/Group	Issue	Engagement Details	Outcome/Purpose
26/10/2017 (Meeting) Whitehorse	YG	Groundwater	Discussed water in pits and groundwater. Brief discussions regarding operational AMP changes.	
17/11/2017 (Meeting) Phone	BTWG	Bioassay frequency reduction	Minto proposed a reduction in bioassay monitoring frequency for the upcoming licence amendment application	Minto to draft up a memo outlining changes.
15/12/2017 (Meeting) Whitehorse	BTWG	General application and RCP update	Discussed changes to the closure AMP, FMEA, WQ predictions, and MWD wrap	Another meeting to be held with SFN technical team providing feedback on the Closure AMP and Wetland treatment systems.
2018				
9/01/2018 (Meeting) Whitehorse	BTWG	Closure AMP and Wetland Treatment System Review	Discussed SFN feedback on Closure AMP and Lorax Wetland review comments.	SFN technical team to provide written Closure AMP feedback.
5/11/2018	BTWG	Phase VII update	Update on status of application and mining (surface mining was completed).	Meeting to provide an update with no specific outcome.
7/4/2018	BTWG	RCP v6	Discussion of RCP v6 (RCP 2018). Four focal areas: Constructed Wetland Treatment Systems, Closure AMP, Closure Costing and Closure Covers.	SFN provided comments on Closure AMP. SFN to provide comments on closure costing.
2019				
12/7/2019	Selkirk Development Corporation	Discussion of exploration plans		
3/8/2019	SFN General Assembly	General update on new ownership and plans		
3/9/2019	Yukon Energy Corporation	Mine plan and energy requirements		
12/9/2019	YG	Regulatory requirements and mine plan discussion with EMR		
29/10/2019	YG	Regulatory requirements and mine plan discussion with EMR and YWCHSB		
6/11/2019	Tripartite working group on SE	Discussion of preparing the 2016 to 2018 report		
15/11/2019	YG	Meeting with Minister Ranj regarding mine plan		

Date, Event, Location	Stakeholder/Group	Issue	Engagement Details	Outcome/Purpose
2020				
14/1/2020	YG	Discussion of CK documents	YG personnel included YWCHSB, EMR and CMI. Focal points included safety (ERP) and ventilation.	
27/1/2020	BTWG	Regulatory and mining update	Update on status of application and mining (re-started the mine).	Meeting to provide an update with no specific outcome.
13/2/2020	Tripartite working group on SE	Discussion of preparing the 2016 to 2018 report and 2020 Household survey		Proceed on 2016 to 2018 report.
17/2/2020	SFN/Yukon College	Site tour as part of workforce readiness course		
5/3/2020	SFN leadership	Principals meeting	General update	
9/3/2020	Tripartite working group on SE	Discussion of preparing the 2016 to 2018 report		Proceed on 2016 to 2018 report.
11/3/2020	YG	Discussion of CK UMDOP		
12/5/2020	BTWG	Discussion of IR#6	Minto provided a number of IR responses and identified other IRs as a topic of discussion	Identified potential approaches to IRs and received feedback from SFN.
15/6/2020	YG	Update on regulatory process/mining with EMR		
23/6/2020	BTWG	Closure AMP (Mine site component)	Discussion of revised approach on mine site AMP. Discussion of SFN's comments on closure AMP.	Update closure AMP based on discussions with SFN.
29/6/2020	Tripartite working group on SE	Discussion of preparing the 2016 to 2018 report		Provided draft report
30/6/2020	BTWG	Closure AMP (Mine site component). W15/W62 new frameworks.	Discussion of revised approach on mine site AMP. Discussion of SFN's comments on closure AMP.	Update closure AMP based on discussions with SFN.
3/7/2020	Selkirk Development Corporation	Kickoff meeting		
7/7/2020	BTWG	Closure AMP (constructed wetlands component)	Discussion of revised approach on closure AMP. Discussion of SFN's comments on closure AMP.	Update closure AMP based on discussions with SFN.
16/7/2020	Selkirk Development Corporation	Bi-weekly meeting		
16/7/2020	YG	Update on regulatory process and mining		
22/7/2020	Tripartite working group on SE	Discussion of the 2016 to 2018 report		Provided draft report comments
31/7/2020	BTWG	Closure AMP (Minto Creek component)	Discussion of revised approach on closure AMP. Discussion of SFN's comments on closure AMP.	Update closure AMP based on discussions with SFN.

Date, Event, Location	Stakeholder/Group	Issue	Engagement Details	Outcome/Purpose
4/8/2020	Selkirk Development Corporation	Bi-weekly meeting		
5/8/2020	BTWG	Closure AMP (remaining aspects)	Discussion of revised approach on closure AMP. Discussion of SFN's comments on closure AMP.	Update closure AMP based on discussions with SFN.
14/8/2020	BTWG	Security cost calculations	Discussion of security cost calculations	Update security cost calculations after discussion.
17/8/2020	Selkirk Development Corporation	Bi-weekly meeting		
17/8/2020	BTWG	Discussion of surety bonds with expert Lois Innes		
27/8/2020	BTWG	Discussion of transition from PCI to PCII	Discussion of revised approach to transition from PCI to PCII	Update closure AMP and RCP after discussion
1/9/2020	Selkirk Development Corporation	Bi-weekly meeting		
4/9/2020	BTWG	Discussion of scenarios for water quality in PCI and PCII	Discussion of scenarios for water quality in PCI and PCII (re: transition and continuous improvement)	Update closure AMP after discussion
10/9/2020	Selkirk Development Corporation	Bi-weekly meeting		
11/9/2020	BTWG	Site tour		
14/9/2020	YG	Site tour		
15/9/2020	YWB	Site tour		
24/9/2020	Selkirk Development Corporation	Bi-weekly meeting		
30/9/2020	BTWG	Closure AMP (complete draft document)	Review of entire document	Update closure AMP after discussion
9/10/2020	YG	Discussion of regulatory process		Plan to submit closure AMP, ops AMP and security cost calculation
15/10/2020	Tripartite WG on SE	Final review of comments on 2016 to 2018 Report	Discussion of remaining issues in the report and data that was still missing	Update Report
20/10/2020	SFN leadership	Discussion of cooperation agreement		

Appendix C
Memo - Re-evaluation of Candidate Passive Treatment Technologies for Minto Mine Closure

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Memorandum

To:	Ryan Herbert (Minto Explorations Ltd.)
From:	Jim Theriault, Jim Harrington, Scott Keesey (Alexco Environmental Group, Ltd.) Monique Haakensen, (Contango Strategies Ltd.)
Date:	February 26, 2016
Re:	**Re-evaluation of Candidate Passive Treatment Technologies for Minto Mine Closure**

1 Introduction

Passive treatment of mining impacted waters (MIW) in closure and post-closure is being evaluated for the Minto Mine. The Reclamation and Closure Plan (RCP) for the site proposes a transition from active to passive water treatment, and research has been underway to refine performance expectations for the technologies most likely to be successful at the site. These include constructed wetland treatment systems, bioreactors, and in-pit batch biological treatment of MIW. These technologies were previously selected in connection with preparation of RCP v4.0 (Phase IV Mine Plan), based on a methodical evaluation of appropriate technologies for the site.

This memo reviews the decision-making process that was employed to identify the preferred passive treatment technologies and also presents the results of a recent re-evaluation of potential passive treatment technologies that could be effectively incorporated into the new Phase V/VI Minto RCP. It also documents the technologies and best practices that have been incorporated into the reclamation design that ultimately have resulted in the water quality that can be treated by the passive or semi-passive technologies proposed. This includes a number of types of mitigation measures which prevent constituents from becoming part of the MIW, which ultimately results in a minimization of treatment requirements. These prevention technologies are listed in Table 1, and include:

- Administrative controls,
- Backfilling and subaqueous disposal,
- Capping, covers, and grading,

- Diversionary structures,
- Excavation and disposal of solid mine waste,
- Re-use and reprocessing technologies.

These technologies will each be incorporated into closure planning to varying degrees, but will not be considered in the current evaluation of candidate passive treatment technologies. Together the incorporation of these “best practices” result in MIW that will be amenable to passive treatment.

The reasons for this re-evaluation of passive treatment technologies include:

- The technologies were last formally evaluated in connection with the Minto Phase IV mine closure plan. This proposed Phase V/VI Mine Plan has a revised configuration and some changed conditions;
- The YESAB evaluation of the Phase V/VI mine and closure plans contains guidance on how passive treatment should be evaluated and implemented (see Section 3);
- Minto Exploration Ltd (Minto) has committed to work collaboratively with Selkirk First Nation (SFN) on Closure Planning and water quality issues and to seek opportunities for involvement of SFN in both closure implementation and long-term care and maintenance; and
- The process can be used to foster a collaborative approach to optimization of the mine closure configuration. This is consistent with the recognition that Minto mine is in SFN traditional territory and will ultimately be returned to the SFN upon cessation of the mining and full, successful implementation of the RCP.

Specifically, the information presented in this memo is intended to be consistent with “Step 1 – Confirm Technologies” as outlined in an associated memo “Framework for Development of Minto Closure Water Quality Objectives” (August 5, 2015), and incorporates subsequent feedback from SFN related to the proposed process.

As described in the WQO Framework memo, scoping level work to date suggests that there is a good potential that some aqueous constituent load reductions from the site can be expected with passive treatment, but it is possible that these measures will not result in achieving a non-degradation target in lower Minto Creek. Minto is committed, in consultation with SFN, to exerting the best effort possible in refining a reasonable and practical passive treatment plan for Minto. In turn, objectives that are reflective of this plan and protect aquatic resources in lower Minto Creek will also be developed in consultation with SFN.

Minto recognizes the importance of evaluating the achievability of meeting non-degradation targets as outlined in the recent Water Licence Amendment. Minto, with the support of Alexco Environmental Group (AEG), has completed some additional analysis regarding the achievement of non-degradation targets. This analysis (results provided separately) suggest that although some aqueous constituents may reasonably be expected to meet a non-degradation concentration post-closure, many key constituents will not. As a result, the steps and evaluation in this framework remain focused on the key parameters considered previously, and also includes the parameters identified for water quality objectives in the revised Water Use Licence (operational water quality objectives, see section 3.1 below).

Given this introductory information, Section 2 of this memorandum presents background of how the passive treatment technologies proposed in previous versions of the Minto RCP came to be selected, and outlines the ongoing work being undertaken to provide site-specific proof of concept and develop the design basis. Given the changes in the mine plan and closure configuration for the proposed Phase V/VI mine expansion and our improved understanding of contaminant removal mechanisms that have been gained through the ongoing reclamation research program, this document also presents a framework for evaluating the relevance and applicability of a full range of potential passive treatment technologies.

Section 3 of this document then presents the updated ranking and evaluation of the various potential passive treatment technologies and identifies the passive (and semi-passive) treatment technologies that are proposed for consideration in closure planning at the Minto Mine Site. Section 4 identifies how the findings are proposed to be utilized, as next steps.

2 PREVIOUS WORK ON PASSIVE TREATMENT TECHNOLOGY SELECTION

A process for the identification and evaluation of the full range of passive treatment technologies that could potentially be incorporated into closure planning at the Minto Mine site was formally initiated in late 2012, in connection with the preparation of RCP v4.0. The work was initially presented to SFN in the associated preliminary FMEA workshop (January 2013). Prior to this formal process being undertaken, identification of potential passive treatment technologies was incorporated into closure planning at a conceptual level.

At that time, there was already substantial information available with respect to both observed and predicted water quality across the mine site and the anticipated long-term geochemical evolution of MIW. The need for a more formalized approach to identifying potential passive treatment technologies was recognized and the process was initiated in connection with early planning for the RCP v4.0. The framework utilized in the 2012/13 evaluations is outlined below in section 2.1, and is followed by brief summaries of the 2012/13 findings in sections 2.2 and 2.3 respectively.

2.1 FRAMEWORK FOR TECHNOLOGY EVALUATION

The options evaluation for closure reclamation technologies for the RCP v4.0 was based, in large measure, on the Interstate Technology and Regulatory Council (ITRC) mine waste treatment technology selection process, which is described in detail on the ITRC website: http://www.itrcweb.org/miningwaste-guidance/technology_overviews.htm

The ITRC is a public-private coalition and the technical material is developed by teams composed of environmental professionals, including state and federal environmental regulators, federal agency representatives, industry experts, community stakeholders, and academia. This site is continually updated and serves as an aggregator of best practice and innovative emerging treatment technologies and provides relevant case studies to support the design process. The ITRC mine waste technology selection process is recognized as a world class resource for on the topics of innovative mine reclamation and treatment technologies. As such, it was selected to use as the primary tool for identifying and evaluating potential treatment technologies.

The ITRC web-based resources on mine waste treatment technology selection process are designed to help regulators, consultants, industry, and stakeholders in selecting an applicable technology, or suite of technologies, which can be used to remediate mining sites. Through a series of questions, decision trees guide users to a set of treatment technologies that may be applicable to a particular site situation. Each technology is described, along with a summary of the applicability, advantages, limitations, performance, stakeholder and regulatory considerations, and lessons learned. Each technology overview links to case studies where the technology has been implemented.

The decision tree for identifying potential treatment options for mitigating mining impacted groundwater and surface water is presented in Appendix A.

2.2 2012 PASSIVE TREATMENT OPTIONS ASSESSMENT

The 2012 Options Assessment considered the ability of various treatment technologies to treat observed and predicted water quality emanating from seeps at the South West Dump (SWD) and monitoring point W37, immediately downgradient of the dry stacked tailings storage area (DSTSF). The technology evaluation focused on treatment technologies that could address mining impacted water (MIW) as either surface water or groundwater flow.

The 2012 Options Assessment ranked the technologies in a semi-quantitative matrix, using a variety of metrics including:

- Ability to address main contaminants of potential concern (CoPCs; e.g., Cu, Cd, Se),
- Ability to operate in the climate and seasonality of water at Minto,
- Requirement for addition of chemical reagents,
- Ability to operate without constant power source,
- Successful track record in similar conditions,
- Opportunities to engage stakeholders,
- Long-term operational requirements,
- Long-term maintenance requirements, and
- Aesthetics.

The 4 short-listed technologies identified in the 2012 evaluation were: 1) constructed wetland treatment systems (CWTS), 2) biochemical reactors (BCR), 3) permeable reactive barriers (PRB), and 4) in-pit chemical precipitation treatment. Some of these technologies were further evaluated for potential applicability at Minto through the reclamation research program (refer to Section 2.4) to further refine the identification of the most promising passive treatment technologies for incorporation into long-term closure planning.

2.3 JANUARY 2013 PRELIMINARY FAILURE MODE AND EFFECTS ANALYSIS (FMEA)

The ITRC mine waste treatment technology selection process (web based decision tree) was presented at the January 2013 Preliminary Failure Mode Effects Analysis (FMEA) workshop along with the rationale by which the most promising passive treatment technologies were identified (i.e., CWTSs, BCRs, PRBs, and pit lake treatment). The potential application of these passive treatment technologies was then brainstormed in the context of evaluating a range of closure scenarios:

Scenario 1 – a source control focus in which emphasis would be placed on installing high quality, low permeability covers and subaqueous disposal of PAG waste rock to limit contaminant loading at the source.

Scenario 2 – referred to as a treatment focus (active and passive), considering minimal covers and source term control but heavy emphasis on treating all MIW before it leaves the site.

Scenario 3 – a hybrid closure scenario that relied on moderate covers (using readily available cover materials and industry practices for grading and revegetation) and incorporation of passive treatment technologies (with active treatment as contingency) to further improve water quality and decrease contaminant loads leaving the site.

Scenario 3 was ultimately endorsed and closure concepts including revegetated soil covers and passive treatment technologies were further developed in the Phase IV RCP.

It should be noted that subsequent to the 2013 FMEA, the site-wide geochemical modeling inputs were updated with new information and resulted in greatly improved estimated closure water quality relative to the working assumptions at the time of the 2013 FMEA.

2.4 PASSIVE TREATMENT RECLAMATION RESEARCH PLAN (RRP)

The results of the initial passive treatment technology evaluation, and subsequent feedback from the January 2013 FMEA workshop, were further considered by Minto and subject matter experts from AEG and Contango to develop a robust reclamation research plan for passive water treatment (RRP). The goal of the ongoing RRP is to enable, within the site-specific context of the Minto project, the determination of 1) proof of concept of each technology, 2) the anticipated treatment potential and 3) the design parameters required for more detailed design and costing of the proposed passive treatment technologies at closure.

The RRP for passive water treatment was initiated in 2013 and was designed to focus on CWTS and BCRs. The passive treatment RRP was designed to provide additional insight into innovative ways in which CWTS and/or BCRs could be applied at site, and potential to be combined as a treatment train to provide maximum flexibility for a wide range of potential closure scenarios. Studies to evaluate the potential for batch treatment of pit-lakes (i.e., limnocorral trials) were already underway as that study had been initiated in the fall of 2012 (discussed below). Although permeable reactive barriers were initially identified as a potentially promising technology, they were not specifically evaluated through the RRP due to the anticipated challenging subsurface conditions (discontinuous permafrost) and limited areas of potential applicability. However, it was recognized that the proposed research into BCRs could provide relevant information to the potential applications and benefits of PRBs in a closure context.

The passive water treatment RRP included dedicated site visits with associated field and laboratory testing programs to provide preliminary characterization of potential treatment areas (Contango 2014a). Additionally, locally available borrow sources were sought out for substrates and vegetation that could be incorporated in passive treatment design. The initial field program identified areas where natural attenuation and treatment of MIW are already naturally occurring on-site and provided additional insight into potential treatment mechanisms. The approach being used to design the passive water treatment systems involves a phased approach, starting with off-site pilot-scale testing and optimization (at Contango's facilities in Saskatoon). The pilot-scale trials (medium-size trials in large barrels) included different combinations of soils/substrate and vegetation to allow for selection and optimization of the best design for the Minto site (Contango 2014b). The systems were designed to provide specific insights into the biogeochemical process-driven steps. The pilot-scale tests were fully instrumented, monitored regularly, and subjected to a variety of potential site conditions and water quality scenarios. The pilot-scale tests were run in a controlled facility, allowing for accurate evaluation of how different aspects affect the performance of the systems (e.g., nitrate, water depth) without the influence of other external and confounding factors. At the end of pilot-scale CWTS testing, additional organic material (straw and hay) were added to the wetland cells converting them to a hybrid CWTS/bioreactor. This provided a preliminary proof of concept for the feasibility of a semi-passive hybrid CWTS/bioreactor as a contingency option. The results of the pilot-scale testing were used to further optimize the design, and enabled refinement of sizing and set design, performance, and timeline expectations for the scale-up to a larger demonstration-scale treatment wetland to be constructed at Minto.

In the fall of 2014, an on-site demonstration-scale CWTS was constructed on the Minto Site to evaluate the effectiveness for treating actual MIW. The demonstration-scale system is constructed as four cells (two systems in parallel, each made of two cells in a series). The demonstration-scale CWTS has been progressing through commissioning as expected based on the pilot-scale testing, and is beginning to treat water (Contango, 2015; Capstone Mining, 2015).

Concurrently, dedicated research into the potential effectiveness of bioreactors has been undertaken at Yukon College both in lab facilities and at the Minto site. Lab-based testing utilized synthetic effluent to examine metals removal in sulphate-reducing conditions; these results are documented in Janin and

Harrington (2014). On site testing provided water from W37 to a series of reactors which utilized wood chips, ethanol, or wood biochar as substrates with gravel. Removal of selenium, copper, and nitrogen compounds was evaluated over a 2+ month operating window, and showed effective removal for both selenium and copper, and no detrimental effects to nitrogen compounds.

Limnocorral studies were undertaken prior to the development of the RRP and so it was not necessary to include additional pit-lake treatment studies as part of the RRP. In brief, to evaluate the potential for batch treating open-pit water, limnocorral studies were initiated in the Main Pit at Minto in October 2012 and ran through to the spring of 2013. The trials evaluated the feasibility and effectiveness of batch treating pit-lake water by addition of select carbon sources (sugars, alcohols and wood chips) to create reducing conditions (i.e., negative oxidation-reduction potential) that would in turn facilitate the precipitation of metals as sulphides and selenium as elemental selenium. Initial limnocorral tests provided promising results for metals treatment. If selected as a technology to pursue for implementation, additional research would be required to further develop the site-specific approach for batch treatment of the pit-lake water at Minto.

The passive water treatment RRP was initially designed to address the anticipated closure water quality conditions of the Phase IV mine plan. The proposed Phase V/VI Mine Plan contemplates changes to both the closure water conveyance network and to potential sources of contaminant loading. Consequently, the range of potential passive treatment technologies that might be applicable to the updated mine configuration will be evaluated anew.

3 UPDATED EVALUATION OF POTENTIAL PASSIVE TREATMENT TECHNOLOGIES

The Decision Document issued following the YESAA Screening of the Minto Mine Phase V/VI Expansion project proposal provided the following guidance for the development of closure WQOs:

> *#33. …Non-degradation (compared to historical background quality) of Minto Creek water quality shall provide the basis for the development of water quality objectives for the closure period. However, if non-degradation cannot be achieved using reasonable and practical passive treatment mitigations, then the closure objective shall be guided by what can be practically achieved (as long as the objectives are below the effects levels for aquatic resources with sufficient contingency). Determination of "reasonable" and "practical" mitigations must take into account the expected or actual site performance of a given mitigation, and the cost of the mitigation (both initial cost and long-term maintenance cost) compared to the expected contaminant reductions.*

This memo is designed to identify which particular technologies are considered as a 'reasonable and practical' basis of a long-term site-specific passive water treatment implementation strategy in the context of the Minto site. What is considered 'reasonable and practical' will depend on site-specific considerations and expectations of long-term operational and maintenance activities. For the purposes of evaluating and refining technology selections for passive water treatment and the Minto site, 'reasonable and practical' has been defined as having the following criteria:

- Operationally passive:
  - Self-sustaining in the long-term (e.g. minimal need for electricity or chemical addition)
  - Minimal ongoing operational oversight required
  - Does not require active decommissioning activities
- Minimizes long-term maintenance:
  - Able to naturalize, with only periodic and limited maintenance requirements
  - Most maintenance can be performed manually (i.e., does not require heavy equipment)
  - No routine addition of substrates or organics

In this context, it is recognized that even passive treatment technologies will require some operation and maintenance during commissioning. Moreover, several technologies under evaluation can span between passive to active, depending on their approach to implementation. For technologies that may be implemented in different forms, only the most passive options are being considered as priority options in terms of being ‘reasonable and practical’ for the Minto site.

An updated reclamation and closure plan (RCP) was prepared for the Phase V/VI expansion. A Failure Modes and Effects Assessment (FMEA) workshop, attended by representatives from MEL, YG and SFN, was conducted in the summer and fall of 2014 to evaluate the latest iteration of the RCP (v5.1). The FMEA identified potential risks associated with closure water quality and also identified a need to address the topic of defining “reasonable and practical” passive treatment technologies to assist with the development of closure WQOs.

It was recognized at that time that a complete reassessment of the full range of potential passive treatment technologies was warranted, to ensure that any changing site conditions and/or emergent technologies were factored into the potential passive water treatment technology selection. A re-visiting of relevant site conditions was undertaken (Section 3.1) and the ITRC Process was then re-applied (Sections 3.2 – 3.5).

3.1 SUMMARY OF SITE CONDITIONS RELEVANT TO TREATMENT TECHNOLOGY EVALUATION

The following section briefly summarizes the specific site conditions that are directly relevant to closure planning and passive water treatment planning at the Minto mine site:

- Remote: The site is relatively remote. Accessing the site requires crossing the Yukon River via barge / ice dam or flying in via plane or helicopter. Once the closure plan is fully implemented, the airstrip would be decommissioned and barge service discontinued. Remobilization of heavy equipment would require temporary remobilization of the barge.

- Climate: The site is located in the sub-arctic ecoregion and experiences extreme cold during the winter months and a pronounced spring freshet.

- Contaminant Sources: The primary sources of ongoing contaminant loading in closure include waste rock dumps, dry stacked tailings, historic ore and concentrate stockpile areas and pit walls. Of these potential contaminant sources, the Southwest Dump and Drystack Tailings (DSTSF) account for the majority of predicted contaminant loads. The associated seepage from these contaminant sources has been monitored for years and the observed contaminant loadings add a significant degree of confidence to water quality predications.

- Site Configuration: The site is essentially confined to a single watershed which progressively constricts to a single point of discharge downgradient of the DSTSF (current spillway through the Water Storage Pond Dam). The majority of mining impacted water upgradient of the DSTSF is routed through completed open-pits (which provide flood attenuation and additional residence time).

- Natural Attenuation: Significant reduction in contaminant loading is observed in the "wetland" area adjacent to sampling point W15. The observed contaminant load reduction in this flooded, natural area provides strong evidence that naturalized wetlands have the potential to provide ongoing passive treatment to mining impacted waters on site.

- Timing of Contaminant Flux: Evaluation of flow and concentration profiles from the mine has shown that peak flows typically occur in April and May, and that the metals loading distribution follows flow.

- Contaminants of Potential Concern: Aqueous metal and metalloid concentrations in site seepage and runoff are the primary focus of planned load reduction through passive treatment, as N-species (NH4, NO3 and NO2) concentrations are not anticipated to persist in post-closure conditions as they are a product of active operational blasting activities, and decay relatively quickly after these activities cease. The remaining COPCs identified in the current water use licence as parameters for which there is an operational water quality objective are:

    - Aluminum
    - Arsenic
    - Cadmium
    - Chromium
    - Copper
    - Iron
    - Lead
    - Molybdenum
    - Nickel
    - Silver
    - Selenium
    - Zinc

  These are the contaminants of focus for the ongoing evaluation of passive treatment options at Minto.

3.2 REVIEW OF THE ITRC MINE WASTE TREATMENT TECHNOLOGY DECISION FRAMEWORK

The ITRC mine waste treatment technology decision framework currently includes a total of 22 potential technologies (prevention and treatment) that could be applied to mitigate and/or treat mining impacted surface water and ground water. The list of technologies is reviewed and updated frequently by the ITRC and is comprehensive, spanning operational life and mine closure, and includes both passive and active technologies.

The list of potential treatment technologies includes several active treatment technologies that do not meet the initial screening criteria (Section 2.1) of requiring no consistent power supply and a need to have low or no operation and long-term maintenance requirements. The active treatment technologies eliminated include: electrocoagulation, electrokinetics, ion exchange, and pressure driven membrane separation (e.g., reverse osmosis).

3.3 ADDITIONAL RESOURCES CONSIDERED

In addition to the ITRC decision framework referenced above, the following resources were also reviewed to ensure that all relevant passive treatment technologies have been considered:

1) Mine Environment Neutral Drainage guidance documents: http://mend-nedem.org/guidance-documents/
2) GARD guide: http://www.gardguide.com/
3) Alberta Environment published a review report titled “Evaluation of Treatment Options to Reduce Water-Borne Selenium at Coal Mines in West-Central Alberta”.
4) CH2M Hill prepared a review report for North American Metals Council titled “Review of Available Technologies for the Removal of Selenium from Water”
5) Golder prepared a review report for Teck titled “Literature Review of Treatment Technologies to Remove Selenium from Mining Influenced Water”.
6) MSE prepared a report for US EPA and Department of Energy titled “Selenium Treatment/Removal Alternatives Demonstration Project”.

3.4 LONG LIST OF POTENTIAL PASSIVE TREATMENT TECHNOLOGIES

The long list of potential MIW mitigation methods/technologies is presented in Table 1. This table addresses each technology at a high level, provides general comments about the applicability of each technology to Phase V/VI closure planning, the current status of evaluation of the technology or approach, and how that technology could potentially fit into Minto-specific closure planning.

As noted in Section 1, six (6) of the seventeen (17) long-listed methods/technologies are already incorporated in the existing designs of Minto Mine closure. In addition, six (6) are considered not relevant to site conditions at Minto (aeration treatment systems, anoxic limestone drains, chemical stabilization, in situ biological treatment, passivation technologies, and phytotechnologies). The rationale for these decisions is provided in the attached tables. This leaves five (5) passive treatment technologies that are considered relevant in the context of identifying "reasonable and practical passive treatment" as defined in the Decision Document. These are:

- Constructed wetland treatment systems;
- Biochemical reactors;
- Permeable reactive barriers;
- In situ treatment of open pits (chemical precipitation through sulphate reduction); and
- In situ treatment of open pits (enhanced biological treatment using algae to sequester metals).

These five (5) treatment technologies are considered further as "short listed" potential passive treatment technologies.

3.5 SHORT LIST OF POTENTIAL PASSIVE TREATMENT TECHNOLOGIES

The short list of potential passive treatment technologies is outlined in Table 2. This list has been maintained intentionally broad in recognition that many of these technologies are "variations on a theme" and can be tailored and/or subject to further optimization in an integrated closure scenario.

Of the five (5) technologies that made the short-list, only one (1) has been identified as a primary passive treatment technology in the Minto Mine closure context – CWTSs. This is primarily based on the level of site-specific research that has been conducted at the Minto site, and the technologies' 'readiness' for advanced design- level integration into the current closure planning.

Four (4) additional technologies are presented as candidate contingency passive treatment technologies – BCRs, PRBs, and two variations of in-situ batch treatment in open pits. Batch treatment of open-pits is subdivided into sulphate reducing batch treatment (which removes metals by precipitation as sulphides) and enhanced biological treatment (which removes metal by algae sequestration which then sinks to the base of the pit). These measures can be considered at a 'contingency' plan level of integration into current closure planning at the Minto site, but would require further site-specific experimentation to be able to refine performance expectations.

4 PROPOSED PATH FORWARD

This document should serve as a foundation for the further development and refinement of:

1. Closure Water Quality Objectives – This technical briefing document is a reference for the ongoing collaborative work underway in the Closure WQO development. The next step (Step 2 – Develop Configuration Options) of the framework is underway, and preparations are being made for Step 3 (Select Configuration and Implementation Strategy); and
2. Refinement of the RCP v6.0 Reclamation Research Plan – this document in combination with outcomes of the WQO Framework will advise the intent and content of the research programs that will continue at the Minto Site.

5 REFERENCES

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TABLE 1
FULL LIST - ITRC MINE WASTE MITIGATION TECHNOLOGIES (PREVENTION AND TREATMENT)
RE-EVALUATION IN CONNECTION WITH PHASE V/VI RCP

TECHNOLOGY	CATEGORY (TREATMENT OR PREVENTATION)	BASIC DESCRIPTION	POTENTIAL APPLICABILITY FOR MINTO CLOSURE	STATUS OF EVALUATION	CLOSURE ROLE
Administrative and Engineering Controls	Prevention. (Already Incorporated in Closure Planning)	Administrative controls (ACs) are nonengineered instruments intended to minimize the potential for human exposure to contamination by limiting land or resource use. Engineering controls (ECs). ECs are physical controls put into place to prevent human and ecological exposure to contamination. Several other technologies listed in this table (e.g., capping, covers and grading; diversionary structures; backfilling and subaqueous disposal) also fall within the broad EC category.	Incorporated into all aspects of closure planning.	Key concerns were flagged in connection with ongoing planning and consultation, and most recently in connection with the Closure FMEA. Incorporated into AMP.	Incorporated into AMP as well as monitoring and maintenance planning. Does not play a role in the evaluation of "reasonable and practical" passive treatment.
Aeration Treatment Systems	Treatment of anoxic or high BOD waters. (Not Relevant)	Aeration involves the mechanical introduction of oxygen into the MIW stream through a variety of techniques with the goal of oxidizing specific dissolved metals species into less soluble forms. Aeration can use gravity and/or mechanical devices to increase the concentration of dissolved oxygen in MIW, promoting oxidation of ammonia, and metals and metalloids such as iron, manganese and arsenic. Some other metals species may also bind to the iron or manganese.	The elements treated by aeration are not relevant to the MIW at Minto. Generally not relevant to Minto unless BCRs or PRBs create a high BOD in outflow water, aeration could be incorporated (gravity flow) to reoxygenate water for receiving environment. Aeration could potentially play a role in oxygenating low oxygen waters to support aquatic ecosystem health.	The role of aeration will be considered in the context of the water chemistry and constituents needing removal from the water, in connection with water conveyance along primary ditches and adjacent to passive treatment zones.	Will be evaluated if needed downstream of BCRs or PRBs to reoxygenate waters. Design principles are well understood. No requirement for specific field trials.
Anoxic Limestone Drains	Treatment of acidic water. Semi-passive. Finite life-span. (Not relevant based on current/predicted water quality)	Anoxic limestone drains (ALDs) are passive treatment systems that can be used to treat the acidity of mine-influenced water (MIW) under specific geochemical conditions. ALDs consist of a buried bed of limestone ($CaCO_3$) engineered to intercept anoxic, acidic MIW and add alkalinity through dissolution of the limestone.	Not relevant to treatment of Minto MIW as the seepage is circumneutral. The technology is well understood by the closure design team and could be incorporated if acidic condiitons develop.	Not appropriate as a key technology for Minto (based on our understanding of the site wide geochemistry), but this technology is well understood by the design team and will be incorporated in the design of passive treatment systems if conditions warrant.	Not currently planned.
Backfilling and Subaqueous Disposal	Prevention. (Already incorporated in closure planning)	In its most basic form subaqueous disposal involves removal of surface material and placing it underground and/or under water, thus eliminating direct contact exposures. It is typically applied to sulfide-containing solid mine wastes to reduce oxidation of the wastes, thus limiting acid generation and/or neutral metals release. It has also been used to dispose of non-acid-generating solid mine wastes through backfilling.	This is being incorporate in the closure planning with tailings and ARD/ML waste rock being deposited in completed open pits which will flood and submerge the mine waste at closure	Saturation of PAG waste rock has always been a part of closure planning at Minto. Minto's Water Use Licence also contains specific language that requires that potentially reactive waste rock associated with the Phase V/VI mine expansion will remain saturated in perpetuity under closure conditions and requires further evaluation of maximizing the backfilling of tailings and mine waste in exhausted open-pits and mine workings.	Mine plan currently being revised to optimize backfilling and subaqueous disposal - consistent with WUL requirements. The implications of subaqueous disposal are already incorporated in WQ modeling and further optimization is not part of current discussion of additional "reasonable and practical" passive treatment technologies for developing closure WQOs.
Biochemical Reactors (BCRs)	Treatment. Semi-passive. Finite life-span. (Proposed in existing closure planning. Re-evaluated as a contingency technology due to finite life span)	Biochemical reactors (BCRs) treat mining-influenced water (MIW) by using microorganisms to transform contaminants and to increase alkalinity in the treated water. The most commonly used BCRs for treating MIW are operated anaerobically (no oxygen) and are also called "sulfate-reducing" bioreactors. The microbial process of sulfate reduction produces sulfide and bicarbonate within the reactor, allowing the target metals such as cadmium, copper, nickel, lead, and zinc in MIW to precipitate as metal sulfides at pH values above 5.0. Biological selenium reduction (treatment) also occurs under these conditions. The bicarbonate produced through sulphate reduction promotes an increase in pH and will promote the removal of some metals as carbonates such as $FeCO_3$ and $ZnCO_3$ under the appropriate conditions.	This technology is semi-passive, requiring periodic maintenance (e.g., injection of carbon source and/or periodic replenishment of porous media). As such, their applicability is considered to be limited to early in the closure period (i.e., PC1) after which time the BCR would no longer be maintained. The exhausted BCR would either be decommissioned or left in place in a geochemically stable condition. They could be installed as stand-alone treatment features (potentially to treat concentrated seepage at the toes of waste rock dumps or the DSTSF), but more likely in connection with a CWTS, where the CWTS would perform treatment once the BCR is no longer effective.	BCRs are being evaluated in connection with the ongoing RRP in coordination with Yukon College.	This research is being conducted in connection with the RRP. This is a semi-passive technology that could be employed early in the mine closure process with the intension that the system would be left and cease to be maintained beyond an initial operational period. This technology is considered as a contingency passive treatment technologiy for closure at Minto.

TABLE 1
FULL LIST - ITRC MINE WASTE MITIGATION TECHNOLOGIES (PREVENTION AND TREATMENT)
RE-EVALUATION IN CONNECTION WITH PHASE V/VI RCP

TECHNOLOGY	CATEGORY (TREATMENT OR PREVENTATION)	BASIC DESCRIPTION	POTENTIAL APPLICABILITY FOR MINTO CLOSURE	STATUS OF EVALUATION	CLOSURE ROLE
Capping, Covers and Grading	Prevention. (Already incorporated in closure planning)	Capping or covering of solid mining waste is an effective and proven treatment technology. Installation of a cap or cover on solid mining waste can reduce or eliminate erosion, fugitive dust emissions, and infiltration of water to prevent the migration of contaminants. Caps or covers eliminate direct exposure to solid mining waste by creating a physical barrier that prevents direct contact with the contaminants.	All mine waste will be capped with an isolating soil cover and revegetated to facilitate the naturalization of the site at closure and a return to self-sustaining conditions that are consistent with land use planning goals.	An evaluation of the full potential range of cover designs was completed by SRK in connection with closure planning and preparation of RCP v4.0. The evaluation concluded that the only cover material available in sufficient quantities for use as cover material is overburden from the stripping of the open-pits and mine infrastructure foundations.	All mine waste will be appropriately graded and covered with a minimum 0.5m of revegetated, isolating soil cover. The HGW portion of the SWD will be capped with a very low permeability BGM cover. The anticipated cover performance is already incorporated in the water quality modeling and is not being considered further in the current context of defining additional "reasonable and practical" passive treatment technologies.
Chemical Precipitation (e.g., In-Pit)	Treatment. Passive or Semi-passive if in-pit settling is designed rather than active filtration/removal of precipitates. (Addressed as a contigency treatment technology in current closure planning in the context of in-situ treatment of water in open pits)	Chemical precipitation is a conventional technology used to treat mining-influenced water (MIW), including acid mine drainage, neutral drainage, and pit lake water. Chemical precipitation processes involve the addition of chemical reagents, followed by the separation of the precipitated solids from the cleaned water. Typically, the separation occurs in a clarifier, although separation by filtration or with ceramic or other membranes is also possible. Chemical precipitation can also be used in pit lakes or other water bodies, in which case the precipitated solids can simply settle and remain in the bottom of the pool.	Potential for significant role as contingency for treating Area 2 Pit water quality. Potential for carbon loading to turn the pit water reducing (encouraging sulphate reduction) and precipitate metals (e.g. Cu, Cd) as sulphides, and reduce SeIV and SeVI to elemental selenium (Se0) which would all settle to the pit bottom. This treatment technology overlaps with In-Situ Treatment of Pit Lakes (below).	Limnocoral trials were completed over the fall/winter of 2013/14. Evaluation to date has focused on creating sulphate reducing conditions to precipitate metals as sulphides (with an emphasis on treatment of Se). Batch treatment of Open-Pits is incorporated in the RRP. Limnocoral trials have confirmed the presence of selenium reducing bacteria and provided proof of concept. Currently considered a contingency treatment technology. The potential application of enhanced biological treatment (algae precipitation) is relatively well understood based on the Grum Pit trials at Faro.	Preliminary limnocoral trials in main pit provided proof of concept. Additional study (limnocoral) will likely be undertaken as Area 2 Pit begins to fill towards the end of the mine life. It is anticipated that batch treatment of Area 2 Pit will remain a contingency plan for closure. No requirement for additional study at this time.
Chemical Stabilization, Phosphate and Biosolids Treatment	Prevention. (Not practical at Minto)	Chemical phosphate treatments have used a variety of phosphate species, but phosphoric acid has been demonstrated to be the most effective. Organic sources of phosphate such as biosolids or composted animal wastes have also been used to stabilize, reclaim, and revegetate barren mine and mill wastes.	Not considered at the Minto Site due to a lack of readily available, cost effective source materials. Other, more appropriate treatment options are readily available.	Not considered for application at Minto.	Not applicable. Dropped from further consideration.
Constructed Wetland Treatment Systems (CWTS)	Treatment. Passive or Semi-passive. Can be designed for long-term, perpetual treatment. (Proposed in existing closure planning)	Constructed treatment wetlands are man-made biologically active vegetated systems that are characterized by saturated soil conditions and at least periodic surface or near-surface water designed specifically to treat contaminants in surface water, groundwater, or waste streams. The wetlands can be designed to operate either aerobically, or anaerobically, depending on the water treatment requirements. The CWTS can be operated as part of a treatment train (e.g., after BCR or in pit treatment).	Several areas are currently being considered. The most significant area is immediately downgradient of the DSTSF and MVFE (treating W37 seepage) and the area around W15. The area around W15 is already functioning as a natural treatment wetland. Evaluations are ongoing for ways to further enhance treatment peformance. Open pit overflow (i.e., Pit 2) is also being considered for treatment.	One of the primary passive treatment technologies being evaluated for Minto. Described in detail in the Reclamation Research Plan. Detailed pilot-scale trials specific to Minto have already demonstrated proof of concept and anticipated removal rates for CoCs for a given surface area, as well as developped the preliminary design considerations. Minto is currently operating an on-site demonstration CWTS to optimize design and refine full-scale sizing requirements.	Will be incorporate into long-term treatment of MIW. Next step is to confirm specific areas for implementation on the mine plan (closure configuration) and confirm available footprint and anticipated outflow water quality based on removal rates (developed from demonstration scale wetland), inflow water quality, and flow rates.
Diversionary Structures	Prevention. (Included in existing closure planning)	Diversionary structures are designed to prevent clean water from becoming MIW by coming into contact with mining solid waste (net acid-producing materials) and/or to divert MIW to treatment or collection systems and away from sensitive environments. Diversionary structures can be used to reduce the volume of, or exposure to, MIW that may present risks to human or ecological receptors and also to prevent/reduce erosion.	Incorporated where possible to both protect mine closure infrastructure and minimize contact of clean water with mine waste. Examples include the Tailings Diversion Ditch and the various primary and secondary water conveyance ditches.	Diversionary structures are already designed for the currently anticipated Phase V/VI closure configuration.	Incorporated in closure planning as appropriate. Concepts are well understood and there is no requirement for additional research in connection with the development of WQOs.

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RE-EVALUATION IN CONNECTION WITH PHASE V/VI RCP

TECHNOLOGY	CATEGORY (TREATMENT OR PREVENTATION)	BASIC DESCRIPTION	POTENTIAL APPLICABILITY FOR MINTO CLOSURE	STATUS OF EVALUATION	CLOSURE ROLE
Excavation and Disposal of Solid Mine Waste	Prevention. (Included in existing closure planning. Largely duplication of Backfilling/ Subaqueous disposal category)	Soil, sediment, or tailings can be removed so that the remaining contaminant concentrations meet a risk-based cleanup level or removed to a certain depth or areal extent so that the clean backfill placed on top of the remaining contamination creates a physical barrier preventing direct contact with the contaminants.	This is already incorporated into closure planning to the degree practicable in the form of excavating pockets of contamination (e.g., areas around concentrate piles or Pelley bone-yard) and dispolsal in engineered landfills or with other reactive mine wastes as appropriate. Application to larger volumes of contaminated mine wastes (e.g. waste rock) is generally covered under backfilling and subaqueous disposal of mine waste (described above) and is a specific requirement within the most recent WUL conditions.	Mine plan is currently being updated to ensure consistency with the WUL requirements. PAG rock that is excavated during the next mine phase will be stored in areas that will be saturated under closure conditions.	This is already incorporated in closure planning ("good practice").
In-situ Biological Treatment	Treatment. Semi-passive. Finite life-span. (Not relevant as defined herein, although partially overlaps with the category chemical precipitation)	In situ biological source treatment consists of isolating the source of mining-influenced water (MIW) through the establishment of an in situ biological layer on exposed metal sulfide surfaces. This is typically accomplished through the injection of inoculum (e.g., wastewater effluent) and substrate into the subsurface material. The in situ biological source treatment can achieve satisfactory results without the cost of excavation and material handling.	Not specifically considered for Minto – although this technology is closely related to BCRs and CWTS which are considered more appropriate technologies for closure application at Minto.	No specific research has been completed. Not specifically considered for closure applications at Minto.	No. Not considered for closure application at Minto.
In Situ treatment of Mine Pools and Pit Lakes	Treatment. Passive or Semi-passive. Can have long-lasting effects, depending on source water and pit characteristics. (Proposed as contingency measure in existing closure planning)	The technology consists of the injection or placement of substances, including (as appropriate) alkaline materials and organic carbon substrate, with nutrients directly into the mine pool or pit lake to neutralize the MIW and to produce anaerobic conditions to precipitate metals in place. Injection of a carbon source such as molasses or alcohol with nutrients and sometimes an alkaline source, such as lime, can create conditions favorable to the precipitation of dissolved metals in place.	Treatment of pit lakes is being evaluated at Minto and is a part of the ongoing RRP. The mine pools are not anticipated to require any treatment. A variation on a theme, which has not been previously discussed for Minto, is encouraging algal growth (through the addition of fertilizer/nutrients) which would scavenge metals and precipitate to the bottom of the pit (e.g., Similar to Grum Pit trials at Faro). Potential challenges with this include potential bioaccumulation of Se as it is taken up by algae; therefore this technology could likely only be considered in combination with initial sulphate reduction to first remove Se from the water column. Enhansed algal growth could be used to maintain treatment conditions semi-passively.	Limnocoral trials were completed over the fall/winter of 2013/14. Evaluation to date has focused on creating sulphate reducing conditions to precipitate metals as sulphides (with an emphasis on treatment of Se). Batch treatment of Open-Pits is incorporated in the RRP. Limnocoral trials have confirmed the presence of selenium reducing bacteria and provided proof of concept. Currently considered a contingency treatment technology. The potential application of enhanced biological treatment (algae precipitation) is relatively well understood based on the Grum Pit trials at Faro.	In-situ treatment of pit lakes (specifically the Area 2 Pit) is being considered as a contingency measure for closure .
Passivation Technologies	Prevention. (Considered not relevant / not practical at Minto)	Technology involves chemically producing coatings on reactive mine waste to limit metals mobility. Typical solutions include use of phosphates and silica. Treatment of acid-generating rock with permanganate and magnesium oxides at a high pH (>12) is a patented process. All passivated surfaces still have reactive rock below the surface, and oxidations will return once that passivation layer is removed. Thus, whether passivation is a viable option depends on time, other environmental conditions, and treatment efficiency requirement.	Not specifically considered in closure planning to date. May have application for treatment of pit walls in the event that ML from exposed surfaces proves problematic in the long-term. Geochemical modelling to dateprovides a high degree of confidence that metal leaching from exposed pit walls at closure is unlikely to be problematic. Passivation technologies typically produce inconsistent and relatively short duration reduction in contaminant loading.	Additional primary research would be required in advance of any large scale trials.	Not explicitely considered in the current RCP.
Permeable Reactive Barrier (PRB)	Treatment. Semi-passive. Finite life-span. (Proposed in existing closure planning. Re-evaluated as contingency treatment technology due to finite life-span and limited applicability in a Minto specific closure context)	In the broadest sense, a permeable reactive barrier (PRB) is a continuous, in situ permeable treatment zone designed to intercept and remediate a contaminant plume. The treatment zone may be created directly using reactive materials such as iron or indirectly using materials designed to stimulate secondary processes, such as by adding carbon substrate and nutrients to enhance microbial activity.	PRBs could potentially be incorporated in very specific applications, as part of a passive treatment train, in areas where space is limited and the potential exists to passively intercept mining impacted groundwater (e.g. immediately downgradient of the DSTSF.	The RRP research into bioreactors and CWTSs, while not explicity directed towards the design of PRBs, provides significant insight into the design and operation of PRBs (i.e., hydraulic, geochemical and microbial characteristics) in a Minto closure context.	This is considered a variation on a theme similar to BCR. Recognized that PRB would likely be used as part of a treatment train rather than as a stand-alone technology.

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RE-EVALUATION IN CONNECTION WITH PHASE V/VI RCP

TECHNOLOGY	CATEGORY (TREATMENT OR PREVENTATION)	BASIC DESCRIPTION	POTENTIAL APPLICABILITY FOR MINTO CLOSURE	STATUS OF EVALUATION	CLOSURE ROLE
Phytotechnologies	Prevention. (Not relevant in WQO context)	Phytotechnologies use plants to remediate various media impacted with different types of contaminants. Phytotechnologies can be applied to address certain issues associated with mining solid wastes and mining-impacted waters. There are six basic phytoremediation mechanisms that can be used to clean up mining-contaminated sites: phytosequestration, rhizodegradation, phytohydraulics, phytoextraction, phytodegradation, and phytovolatilization	All mining waste will be covered with a minimum 0.5m of clear overburden and revegetated. Consideration of specific phytotechnologies, such as phytosequestration and phytohydraulics may be warranted in specific, small scale applications, such as seepage zones, but generally in the context of protection of wildlife and the prevention of metal uptake by plants that could be detrimental to wildlife that consumes those plants (i.e., not to remediate metals in soil).	Not specifically evaluated as a primary reclamation technology for Minto but understanding of the topic (phytosequestration, rhizodegradation, phytohydraulics, phytoextraction, phytodegradation and phytovolatilization) is incorporated in a general sense within the revegetation evaluations.	Consideration of specific phytotechnologies, such as phytosequestration and phytohydraulics may be warranted in specific, small scale applications such as seepage/wet zones – but generally in the context of protection of wildlife and the prevention of metal uptake by plants that could be detrimental to wildlife that consumes those plants.
Re-Use and Reprocess (R^2) Technologies	Prevention. (Incorporated in existing closure planning)	Re-use consists of using problematic mine waste either directly or following reprocessing or other treatment as a beneficial product that is environmentally safe in its re-used form. Reprocessing consists of subjecting mine waste to physical or chemical processes designed to extract minerals or other waste components for beneficial use, rendering the waste material suitable for other beneficial use or environmentally safe disposal on the mine site.	Marginally economic waste rock will be processed as economically feasible. The site is remote site has limited potential for re-use (e.g., use of clean waste rock as rip-rap in streams has proven prohibitively challenging). The WUL specifically prohibits mine waste from being transported off-site.	Optimal reprocessing of marginal waste rock is incorporated in the MWROMP. No further evaluation planned.	Further optimization is not considered. Topic included for completeness.

TABLE 2
SHORT LIST - ITRC PASSIVE TREATMENT TECHNOLOGIES
RE-EVALUATION IN CONNECTION WITH PHASE V/VI RCP

TREATMENT TECHNOLOGY	Status of Evaluation	Steps to Advance	Site Considerations; Reasonable/Practical	Potential Areas of Application	Opportunities for SFN Participation	Key Documents
Primary Passive Treatment Technologies [1]						
Constructed Wetland Treatment System (CWTS)	Highly advanced as documented in the RRP. A field scale CWTS is currently in operation at the Mine Site with the option of converting to a hybrid CWTS/BCR as a contingency. The flooded area around W!5 has also been evaluated in the context of natural attenuation of contaminant loading that is already occuring (in a non-engineered setting) and the potential for enhanced natural attenuation through further optimization and plant species and improved routing of flows.	This is the primary passive treatment technologies being evaluated for Minto. Described in detail in the Reclamation Research Plan. Potential to be converted to a semi-passive BCR if needed as a contingency. Potential sites have been identified and predicted water quality will be refined as data continues to be produced form the on-site demosntration CWTS. Steps 2 and 3 of the "framework for developing Minto closure WQOs" will involve identifying potential sites for incorporating CWTSs (alone or as part of treatment train) under closure conditions.	This is considered both reasonable and practical at the Minto Site and is summarized in Contango (2014a, 2014b and 2015)	Anywhere MIW surface water can be routed through a relatively flat area of sufficient size to accomodate a treatment cell. Whenever possible, should be installed as multiple systems at water sources to reduce loads at the source. A primary area under consideration is immediately downgradient of DSTSF and MVFE. Additionally, the wetland in the W15 area is already naturally functioning in many respects to treat water and could be further enhanced at closure.	Sourcing wetland vegetation. Producing elements of substrate (e.g. wood chips, straw). Construction of the CWTS and monitoring and maintenance during commissioning.	RRP, CWTS site assessmet, CWTS pilot-scale testing, CWTS field-scale construction documents.
Contingency Passive Treatment Technologies [2]						
Biochemical Reactor (BCR)	Somewhat advanced as documented in the RRP. A small-scale BCR is currently in place on site under the design of Yukon College.	Further on-site investigations of seepage sources (quality, variability, flow rates, seasonality) should be undertaken to inform further in-situ research, including demonstration scale reactors. This research would further inform the feasibility of the use of BCRs in the closure planning at Minto.	This technology is semi-passive, requiring periodic maintenance (e.g., injection of carbon source and/or periodic replenishment of porous media). As such, their applicability is considered to be limited to early in the closure period (i.e., PC1) after which time it would no longer be maintained and would be isolated and remain buried in geochemically stable condition. BCRs could be installed as stand-alone treatment features, but more likely in connection with a CWTS, where the CWTS would perform treatment once the BCR is no longer effective. Because BCR are only semi-passive and shorter life span than CWTS, they are most practical to apply as a secondary option where insufficient footprint is available for a CWTS, or concentrations are higher than could be treated by a CWTS. This will need to be evaluated against findings for CWTS feasibility	These are being evaluated in connection with the ongoing RRP and evaluation of CWTS (i.e., to determine which sites would have sufficient area for effective CWTS treatment, and which would need to consider a bioreactor for treatment in a smaller footprint). Potential exists to turn area below the MVFE into a BCR by injecting carbon source to generate sulphate reducing conditions. Still at conceptual level - considered contingency application. If this is done, the CWTS design at that location may need to be revisited as water chemistry will have different treatment requirements (e.g., BOD)	Producing elements of porous media/substrate (e.g. wood chips, granular…). Participation in the construction, monitoring and maintenance during commissioning, and ongoing operation, monitoring, and maintenance.	RRP
Permeable Reactive Barrier (PRB)	This is considered a variation on a theme similar to BCR. It is being evaluated in connection with the RRP. Recognized that PRB would likely be used as part of a treatment train rather than as a stand-alone technology.	Focused review of subsurface information would be required prior to any detailed planning associated with PRBs.	Practical only where groundwater plume is identified and constrained into a groundwater source area that can be channelled.	Best suited where space is limited and groundwater must be passively intercepted/treated - such as immediately downgradient of DSTSF and MVFE.	Sourcing organics for permeable media. Monitoring of operational performance.	RCP v4.0. RRP
In-Situ Treatment of Open Pit (Chemical Precipitation through sulphate reduction)	Limnocoral evaluation has provided proof of concept - suitable for establishing anticipated removal rates of CoCs and required dosing with carbon sources.	Initial limnocoral trials in 2013/2014 have provided proof of concept. Additional trials may be completed as the Area 2 Pit begins to fill during the later stages of Phase V/VI operations.	Proof of concept demonstrated in Main Pit limnocorral trials. Would require mobilization of reagents and equipment for each implementations. Potential application in both Main Pit and Area 2 Pits.	Batch treatment of Open-Pits is incorporated in the RRP. Limnocoral trials have confirmed the presence of selenium reducing bacteria and provided proof of concept. Currently considered a contingency (semi)passive treatment technology.	Monitoring of pit water quality for trends in water quality that would warrant the implementation of batch treatment.	Limnocoral trials
In-Situ Treatment of Open-Pit (Enhanced biological Treatment using algae to sequester metals)	Has not been formally evaluated at this time. Risks identified with potential amplification of Se toxicity as algae could potentially make Se more bioavailable.	Internal discussion. Review the available data from the Grum Pit treatment trials at Faro (program overseen by Lorax). Research implications for Se removal.	Contimant load reduction has been demonstrated at similar sites (e.g., Faro Mine, Grum Pit).	Area 2 Pit. Contingency treatment technology. Would likely only be implemented in combination with batch treatment to drive sulphate reduction to remove Se.	Monitoring of pit water quality for trends in water quality that would warrant the implementation of batch treatment. Application of fertilizer/nutrients to promote algae growth.	Grum treatment evaluations from Faro (additional literature review warranted)

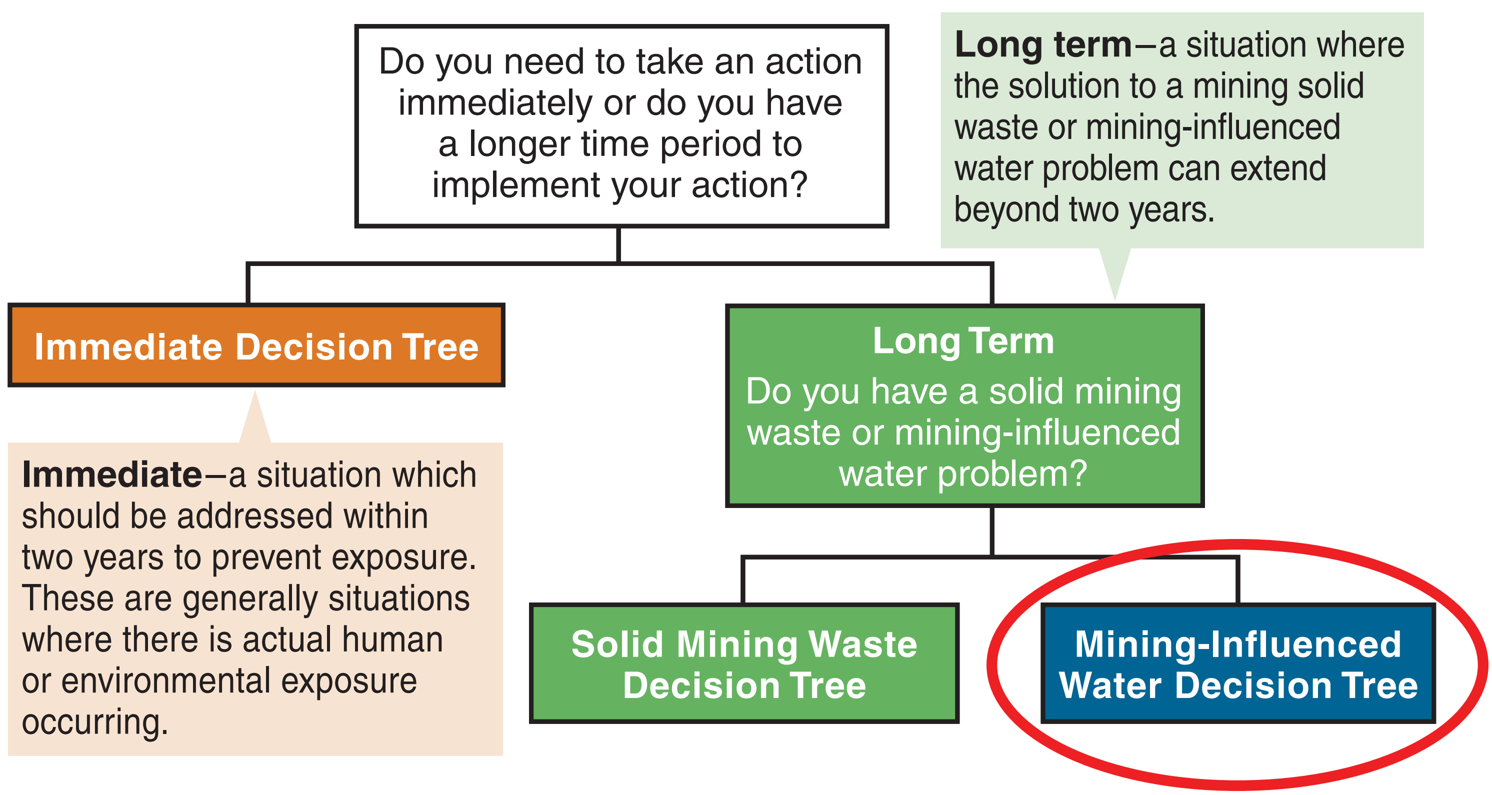
Notes:
1 This technology is considered the most appropriate for evaluation under "Steps 2 and 3" of the Framework for Developing Minto Closure WQO.
2 These technologies are considered "Contingency" passive treatment technologies.

Decision Tree

The Decision Tree has been designed to guide users to a set of treatment technologies that may be useful in managing a particular mine waste site. The user is presented with a series of questions. By answering the questions, the user is directed towards appropriate treatment technologies. Because of the size and complexity of most mine waste sites, there are generally a variety of environmental problems to be addressed. Those problems may include contaminated groundwater, contaminated residential yards, large areas of mine waste, or contaminated surface waters. The user should go through the decision tree separately for each issue to be addressed.

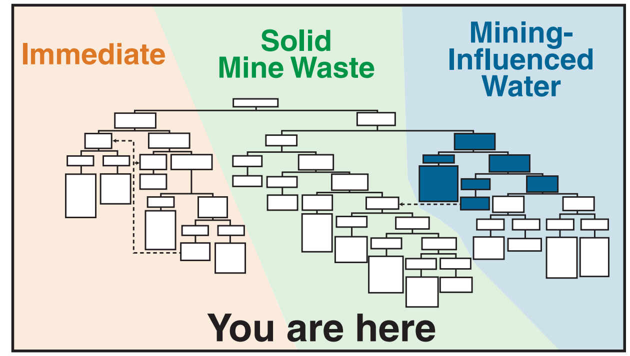
At the end of each string of questions in the decision tree is a list of treatment technologies. Clicking on that list will take users to Technology Overviews where they will learn more about the applicability of specific technologies and supporting case studies.

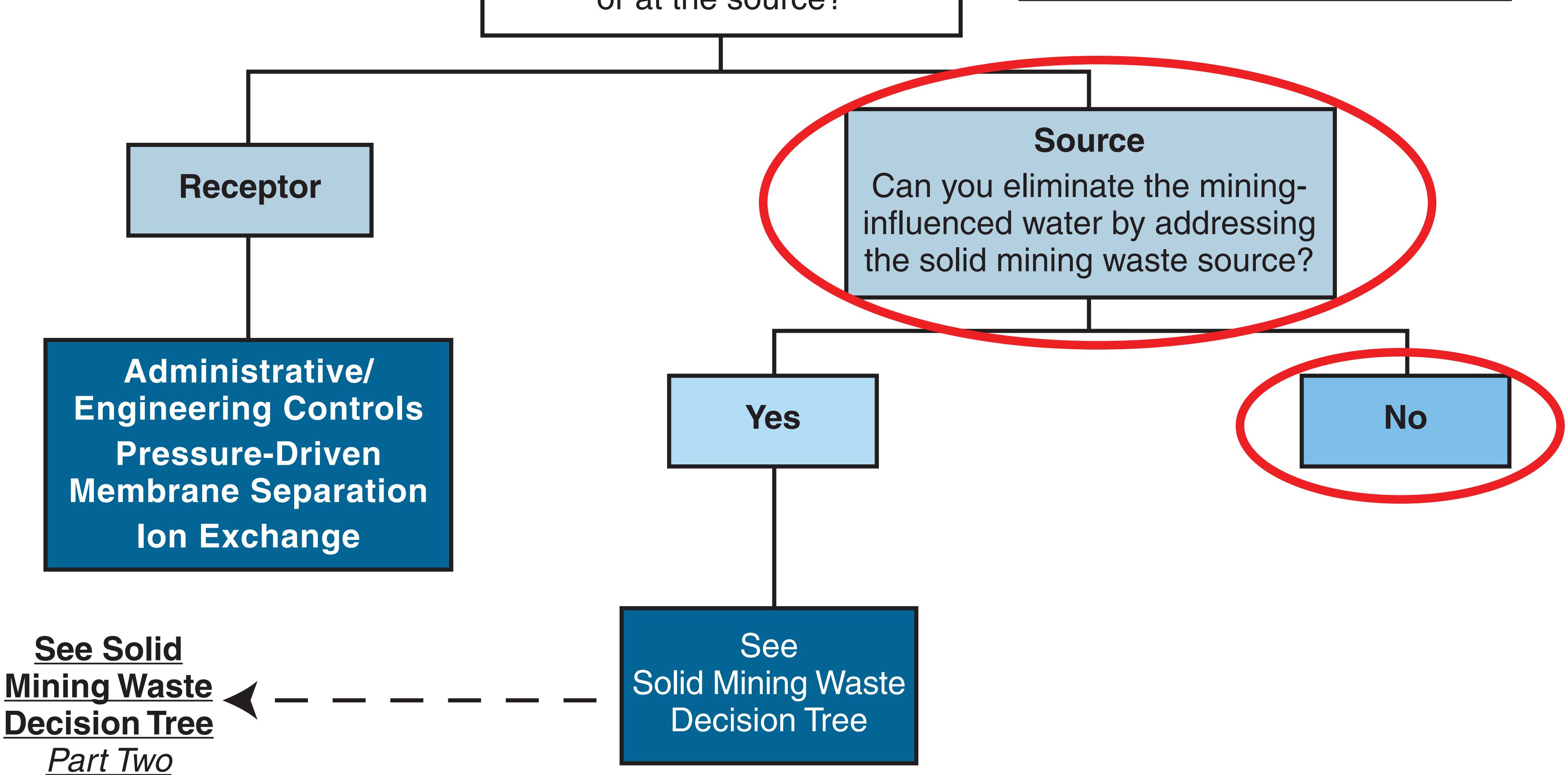
Mining Waste Team Decision Tree—Initial Questions



Mining-Influenced Water Decision Tree

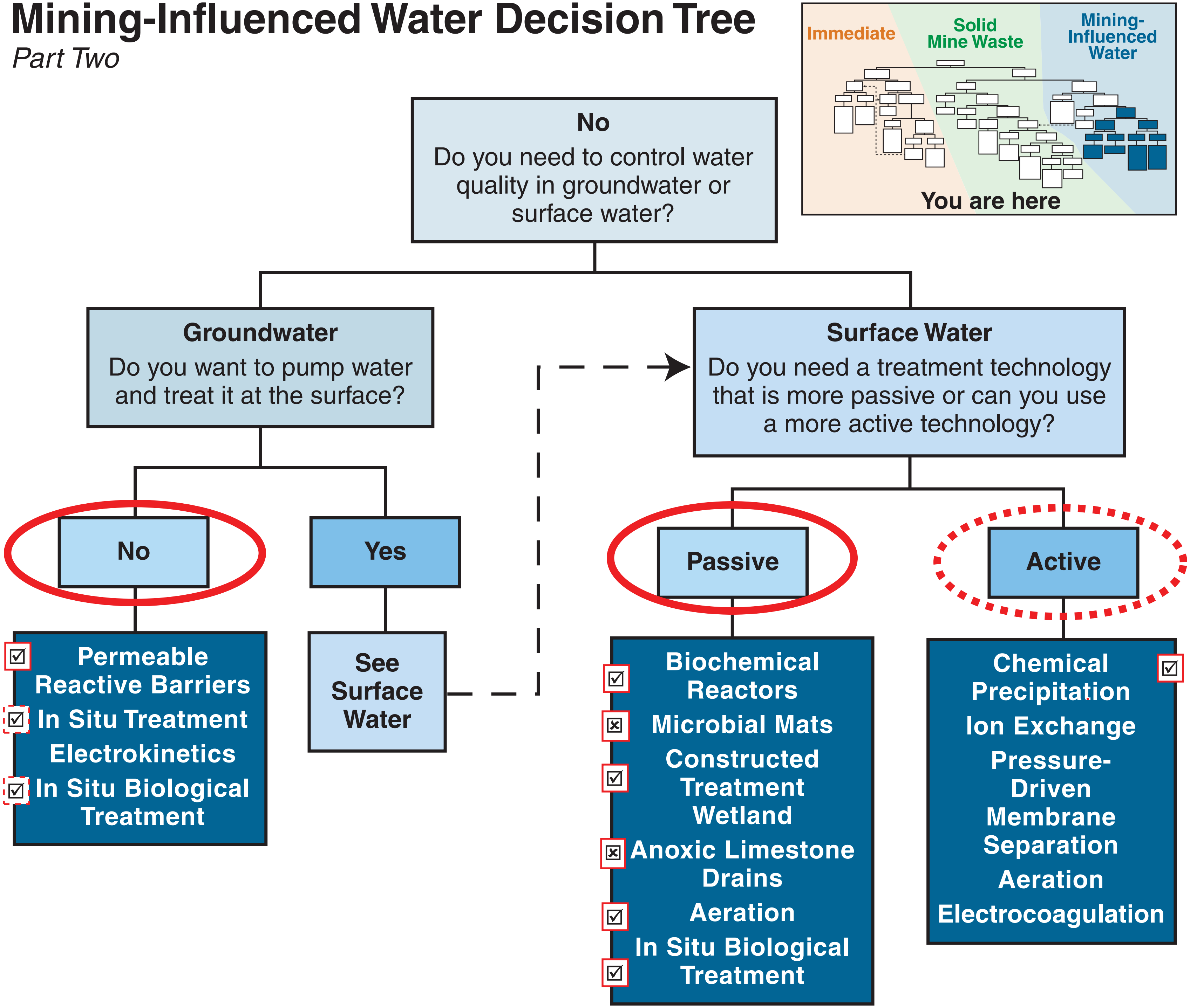
Part One





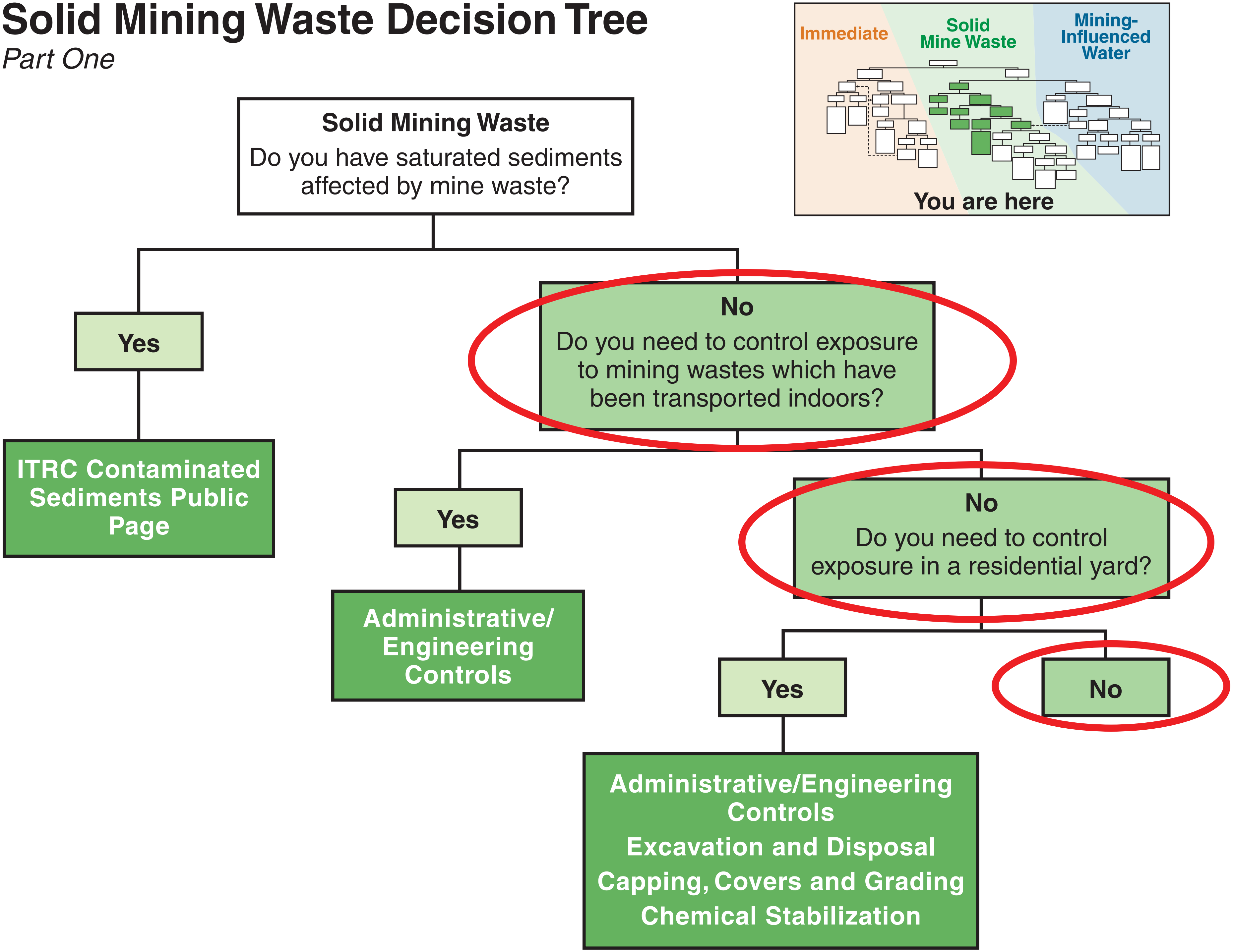
Mining-Influenced Water Decision Tree

Part Two



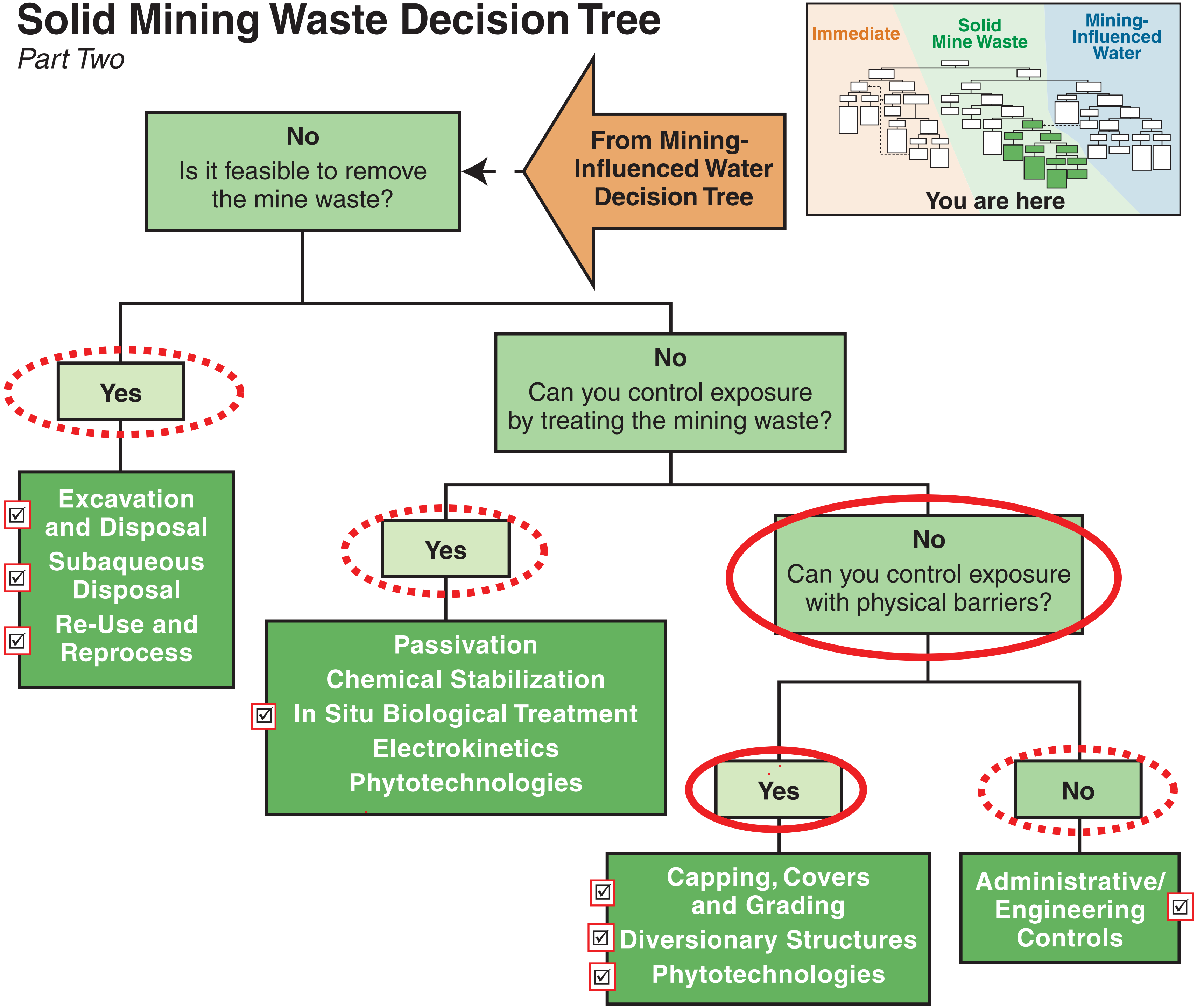
Solid Mining Waste Decision Tree

Part One



Solid Mining Waste Decision Tree

Part Two



Appendix D1
2013 FMEA Risk Register

	Closure Scenario 1: Source Control Focus	Consequence Type	Consequence Severity	Likelihood Probability	Risk Rating Descriptive	NOTES
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 unacceptable 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 unacceptable 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 unacceptable 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	

Appendix D2
Minto Mine Closure - Failure Modes and Effects Assessment 2014 Workshop Report

ACCESS

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.

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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

Consequence Categories	Severity Descriptors				
	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

Consequence Categories	Severity Descriptors: 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	SWD toe seepage collection systems inadequate, leading to unacceptable WQ downstream	3W, 12	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 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	10	Env. Imp.	Moderate	Unlikely	Moderate	Assuming AMP and monitoring will respond to any defects
	B	conditions **downstream of site**		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		Likelihood	Risk Rating	NOTES
		Type	Severity	Probability	Descriptive	
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.

Appendix D3
Minto Mine Closure - Failure Modes and Effects Assessment 2017 Workshop Report

MINTO MINE CLOSURE – FAILURE MODES AND EFFECTS ASSESSMENT

2017 WORKSHOP REPORT

MIN-16-03-_008_Minto Mine Closure FMEA 2017 Final Report_RevA_180123

February 1, 2018

Prepared for:

MINTO EXPLORATIONS LTD.

MINTO MINE

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ALEXCO ENVIRONMENTAL GROUP INC. SIGNATURES

Report prepared by: 13/12/2017

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Report reviewed by: 1/23/2018

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Sr. Environmental Manager

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LIST OF ACRONYMS AND ABBREVIATIONS

ACG	Access Consulting Group
AEG	Alexco Environmental Group Inc.
AES	Atmospheric Environment Service
EMR	Energy Mines and Resources
FMEA	Failure Modes and Effects Analysis
MWD	Main Waste Dump
PCMM	Post Closure Monitoring and Maintenance
RCP	Reclamation and Closure Plan
SAT	Waste Rock that has a NP:AP <3
SFN	Selkirk First Nation
WQ	Water Quality
WUL	Water Use Licence
YESAA	Yukon Environmental and Socio-economic Assessment Act
YESAB	Yukon Environmental and Socio-economic Assessment Board
YG	Yukon Government
YWB	Yukon Water Board

1. INTRODUCTION

Failure Modes and Effects Assessment (FMEA) is a risk evaluation tool that has been used to identify and rank risks associated with the Minto Mine Reclamation and Closure Plan (RCP) since 2013. This report provides a brief background of these exercises and presents a summary of the 2017 FMEA update, which was undertaken to evaluate risks associated with Minto's RCP v2017-01, and to inform planning and mitigative measure selection in RCP v2018-01.

1.1 BACKGROUND

In 2013, 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).

In support of permit amendment applications for the Phase V/VI Expansion mine plan, Minto prepared an updated Reclamation and Closure Plan (RCP v5.1, August 2014). Minto hosted a multi-stakeholder FMEA workshop (in two parts) for the Phase V/VI RCP. The first session was held in Vancouver in August 2014. The two-day workshop in August 2014 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. A second, supplementary FMEA workshop was held in Whitehorse in October 2014 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. The 2014 FMEA Report was included as an appendix to subsequent RCP versions (see Section 1.2).

1.2 CURRENT PLANNING

Per its Water Use Licence condition, Minto submitted an updated Reclamation and Closure Plan in August 2016 (RCP v2016-01) which incorporated changes identified as per the WUL and QML. It included the advancement of closure designs from conceptual to preliminary, as well as an updated water and load balance model, and addressed the narrowed mine plan scope compared to earlier versions of the RCP. A further updated RCP was submitted in March 2017 (RCP v2017-01, March 2017) which incorporated the final Post Closure Water Quality Objectives and an updated Closure Adaptive Management Plan (AMP).

These RCP versions have been submitted to the YWB as a WUL amendment application, and as such have been subject to an adequacy review. On May 26, 2017, YWB issued their Technical Information Request #2, which included the following related to the FMEA:

> ***IR2-15. Please provide an updated closure FMEA that includes all components of the proposed RCO, including water treatment, and deals wit the "parking lot" issues identified on Page 4 of exhibit 1.2 [the FMEA summary report].***

These parking lot issues were items raised in the FMEA for which either not enough information existed regarding RCP details to be able to effectively evaluate the risk (e.g. passive water treatment plan) or the team could not determine an effective way to resolve a difference of opinion, and a 'note' was made in the parking lot. It was identified that the following parking lot items required further consideration:

- 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.

This report provides a description of the 2017 FMEA Workshop proceedings and outcomes, undertaken to meet these YWB information requests, and to inform ongoing planning for the next version of the Minto RCP. It includes the workshop objectives and scope, the approach to the workshop, a description of the workshop activities and the final risk registers developed in the exercise.

2. 2017 FMEA WORKSHOP

In support of the planned RCP revisions and their submission to YWB in the form of RCP v2018-01, and in an effort to supply YWB with the requested information, Minto conducted the first FMEA session in Vancouver on October 18th and 19th, 2017. This was an internal exercise, and is effectively a re-evaluation of the 2014 risk register in the context of any new information. The first (of two) workshops covered site components for which a sufficient level of design currently exists to facilitate this risk assessment. It was focused on site infrastructure (pits, waste rock dumps, dry stack tailings storage facility, water conveyance, covers) and administrative topics. The second workshop was held December 1, 2017 to cover water quality/water treatment topics.

2.1 WORKSHOP OBJECTIVES

The primary objective of the FMEA workshop was to characterize the residual risks that would remain after implementation of the RCP v2017-01, particularly in the context of higher identified risks in 2014 and through a more in depth look at items that were included in the Parking Lot in 2014.

The secondary objective of the workshop was to, for any unacceptable residual risks identified in the ranking exercise, identify potential mitigation measures that would further reduce the overall risk ranking and bring the residual risks into a more acceptable location in the risk matrix. These potential mitigations could then be incorporated into the planning work being undertaken currently for the development of the RCP v2018-01.

2.2 SCOPE AND APPROACH

The FMEA covered Minto's RCP v2017-01 and recent mine plan changes (e.g. inclusion of Ridgetop Pits and Dump) and related design elements for the proposed closure measures. This included RCP elements that were not fully developed in 2014 (e.g. passive water treatment plan, waste dump re-grading plans.) The FMEA was an 'internal' exercise (attended only by Minto management and engineering staff and by relevant engineering and planning consultants) and was focused only on specific consequence types related to traditional engineering and design related-risks and consequences. Further details on the risk rating tools are provided in Section 2.4 and Appendix A.

The FMEA was carried out by revisiting the relevant risk register components and entries from 2014, and modifying the language of the risk/consequence statements and the risk rankings if and where necessary. Risk/consequence statements were added/modified/removed as required.

The FMEA was conducted both on a "Facility" basis (separate risk registers for each type of 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 included:

Facilities:

- Open Pits
- Waste Rock Dumps
- Dry Stack Tailings Storage Facility

Site-Wide Topics:

- Water Quality/Water Treatment

- Water Conveyance
- Administrative

2.3 WORKSHOP STRUCTURE

2.3.1 OCTOBER WORKSHOP

The first FMEA workshop was held at SRK Consulting's Vancouver office on October 18th and 19th, 2017. The workshop was facilitated by S. Keesey of AEG. The two-day workshop included participation by representatives of Minto, Alexco Environmental Group, and SRK Consulting. The topics rated in the October workshop included Pits, Waste Rock Dumps, Water Conveyance and Administrative.

The participants are listed in Table 2-1.

Table 2-1: October FMEA Workshop Participants

Name	Company
Ryan Herbert	Minto Explorations Ltd.
Kevin Cymbalisty	Minto Explorations Ltd.
Scott Keesey	Alexco Environmental Group
Dylan MacGregor	SRK Consulting
Erik Ketilson	SRK Consulting
Sarah Portelance	SRK Consulting
Peter Mikes	SRK Consulting

2.3.2 DECEMBER WORKSHOP

The second FMEA workshop was held at SRK Consulting's Vancouver office on December 1st, 2017 and was again facilitated by S. Keesey of AEG. The one-day workshop included participation by representatives of Minto, Contango Strategies, Alexco Environmental Group, and SRK Consulting. The December workshop was focused on Water Treatment and Water Quality aspects of Minto's RCP.

The participants are listed in Table 2-2.

Table 2-2: December FMEA Workshop Participants

Name	Company
Ryan Herbert	Minto Explorations Ltd.
Monique Simair	Contango Strategies Ltd.
Scott Keesey	Alexco Environmental Group
Soren Jensen	SRK Consulting
Dylan MacGregor	SRK Consulting

2.4 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) which are included in Appendix A. These tools were identical to those utilized by the multi-stakeholder group in 2014 with one exception. As this was in internal risk ranking exercise and was intended to focus primarily on engineering and design aspects of the project, the risk evaluation was limited to the three most relevant consequence types: Environmental Impact, Cost Consequence, and Human Health and Safety. Minto expects to re-visit the FMEA process as a multi-stakeholder process (as a condition of an amended Water Use Licence) and will integrate the remaining consequence types into that exercise with the appropriate stakeholders in attendance. Results of this additional exercise will be included in future versions of the Minto RCP.

The 2014 risk register was simplified in advance by removing the risk 'category' indicator (physical stability, chemical stability, etc.) from the tables and the coding. These generic closure objective considerations were still utilized to organize thoughts and risk types. The revised risk register was circulated in advance to participants of the sessions for familiarity to make the workshop more efficient.

2.4.1 REMOVAL OF SELECT 2014 FMEA RISK STATEMENTS

A select number of risk/consequence statements from the 2014 FMEA were removed from the 2017 register and were not reviewed during the FMEA process. The majority of the entries removed from the register were entries in the consequence categories that were not evaluated (Traditional Land Use, Community/Media/Reputation, and Regulatory/Legal). The remaining removed entries were removed only if the underlying aspects of the entry, such as the mine plan, were no longer relevant.

2.4.2 RISK RATING PROCESS

The remaining risk/consequence statements from the 2014 FMEA were reviewed and the likelihood and consequence for each were determined using the consequence-severity and likelihood tools to reach a consensus risk rating. Additionally, new risk/consequence statements were developed by the group, with their risk rating determined in the same manner. 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. The resultant risk IDs were compiled into risk matrices within the Excel workbook with each risk ID placed in the appropriate cell for its risk rating. An individual risk matrix was developed for each facility and/or topic, as well as a summary risk matrix containing all the risk IDs.

2.4.3 RE-RANKING PROCESS

For a few select risk/consequence statements, the likelihood-consequence ranking was revisited after the inclusion of mitigative measures that are in addition to those included in RCP v2017-01. In some instances, these are measures which were already planned for inclusion in RCP v2018-01. In some other instances, the initial ranking warranted inclusion of different or additional measures (i.e. the risk ranking was unacceptably high.) This 're-ranking' effort was captured in a separate set of matrices (see Section 3) for comparison to the initial risk matrices.

3. FMEA RESULTS

The results of the 2017 FMEA update are described and referenced in the following sections, including the Risk Register, summary and detailed Risk Matrices, risks which were not re-evaluated in 2017 (and rationale) and how 2014 'Parking Lot' items were addressed.

3.1 RISK REGISTERS (APPENDIX B)

These register tables B-1 through B-6 in Appendix B capture following for each topic evaluated:

- the risk and consequence statements with an ID number and consequence category;
- the likelihood and consequence ranking assigned by the team;
- the resultant risk classification for the likelihood and consequence ranking;
- an indication if the risk/consequence statement was changed from the 2014 entry, or if it is a new entry;
- comments that identify assumptions or clarifications regarding the ranking selected; and
- if required – new potential mitigations and 're-ranking' of the mitigated risk.

The ID number of each risk/consequence statement is located on the overall risk matrix, as outlined below in section 3.2. The registers are the most detailed product of the FMEA exercise.

3.2 RISK MATRICES (APPENDIX C)

These 'heat maps' illustrate the overall outcomes of the FMEA ranking exercise. Each risk/consequence statement is placed by its ID number on the matrix in the appropriate risk classification location based on the likelihood and consequence rating. The key to the matrix (Figure 1) and the final 'heat maps' of the exercise (Figures 2 and 3) are presented below, and the full matrices – including those for the individual Topics for both the current (v2017-01) and expected (v2018-01) suites of mitigation measures associated with those RCPs – are provided in Appendix C.

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

Figure 1: Risk Matrix 'Key' with identification of the risk classifications that result from likelihood and consequence ratings.

Likelihood						
Almost Certain	5		D4		D27	
Likely	4		WT18, WT32, W10	WT38, WT42, W5		
Possible	3	P16, P17, P27, WT23, W11	P14, T2, T3, D5, D12, D14, D18, D19, D29, D30, D30, WT11, WT29, WT43, W22, W23, W24, W32	P18, WT21, A4	A5, A6	
Unlikely	2	P1, P19, P21, P22, D10, D24, W29, W30	P8, P9, P11, P12, T1, T7, T11, T12, T13, D6, D11, D13, D20, D31, D31, WT2, WT5, WT8, WT14, WT28, WT30, WT31, WT35, WT36, WT40, W6, W14, W27, W33, W36, W37, A3	WT1, WT4, WT6, WT7, WT9, WT10, WT13, WT15, WT19, WT22, WT34, W28	A1	WT3, WT12
Very Unlikely	1	W3, W4, W15, W17	P23, T4, T8, T9, D23, D26, WT17, WT25, WT26, WT27, WT37, WT41, W1, W2, W8, W16, W18, W19, W20	P5, P6, P10, P15, P20, P24, P25, P26, T10, D1, D2, D3, D7, D8, D9, D15, D16, D17, D21, D22, D25, WT16, WT20, WT24, WT33, WT39, WT44, W7, W9, W13, W21, W31	T5, T6, D28, W12, A8	P7, P13, A7
		1	**2**	**3**	**4**	**5**
		Very Low	**Minor**	**Moderate**	**Major**	**Critical**
		Consequence				

Figure 2: Overall summary risk matrix from 2017 FMEA for RCP v2017-01.

Likelihood		Consequence: 1 Very Low	2 Minor	3 Moderate	4 Major	5 Critical
Almost Certain	5					
Likely	4		WT18, WT32, W10	WT38, WT42		
Possible	3	P16, P17, P27, WT23, W11	T2, T3, D5, D12, D14, D18, D19, D29, D30, D30, WT11, WT29, W22, W23, W24	WT21, A4	A5, A6	
Unlikely	2	P1, P19, P21, P22, D10, D24, W29, W30	P8, P9, P11, P12, T1, T7, T11, T12, T13, D4, D6, D11, D13, D20, D31, D31, WT2, WT5, WT8, WT14, WT28, WT30, WT31, WT35, WT36, WT40, W5, W6, W14, W27, W33, W36, W37, A3	WT1, WT4, WT6, WT7, WT9, WT10, WT13, WT15, WT19, WT22, WT34	A1	WT3, WT12
Very Unlikely	1	P14, D27, W3, W4, W15, W17	P23, T4, T8, T9, D23, D26, WT17, WT25, WT26, WT27, WT37, WT41, WT43, W1, W2, W7, W8, W16, W18, W19, W20, W32	P5, P6, P10, P15, P18, P20, P24, P25, P26, T10, D1, D2, D3, D7, D8, D9, D15, D16, D17, D21, D22, D25, WT16, WT20, WT24, WT33, WT39, WT44, W9, W13, W21, W28, W31	T5, T6, D28, W12, A8	P7, P13, A7
		1	2	3	4	5
		Very Low	Minor	Moderate	Major	Critical
		Consequence				

Figure 3: Overall summary risk matrix from 2017 FMEA for RCP v2017-01 with inclusion of additional proposed mitigation measures being planned for inclusion in RCP v2018-01.

Overall, the exercise returned mostly 'low' and 'moderate' risks associated with the v2017-01 plan. The unacceptable risk areas (high and very-high) contained only three entries. Two of the three were Administrative risk/consequence statements that were not changed from 2014 (although the 2017 workshop team strongly disagrees with the previous risk rating). Further, the 2017 team suggests that the risk has either been mitigated since 2014 (with additional financial security posted with YG) or there is no conceivable way to mitigate the risk, as it assumes violation of future licence conditions. Both entries are of the Cost Consequence category.

The third unacceptable risk statement regarding a failure to relocate SAT material prior to completion of the Main Pit Dump (as with some others) was subject to a 're-ranking' after the identification of additional mitigation measures, which reduced the risk classification from 'very high' to 'low'.

3.3 RISKS NOT RE-EVALUATED (APPENDIX D)

Table D-1 (in Appendix D) includes 2014 register entries that were not re-evaluated. 2014 comments regarding the risk statements were retained, and rationale for the entry not being re-evaluated in 2017 is included. The most common reasons for not re-evaluating entries were:

- The consequence category was not utilized in the 2017 workshop;
- The entry was expanded into a number of more detailed risk statements;
- The entry was a carry over from 2013 and/or is addressed elsewhere and is redundant; and
- The entry pertained to an element of the mine plan or RCP that is no longer relevant (e.g. Main Dam).

The 2017 FMEA team acknowledges that some of these risks are still worthy of re-evaluation, yet is confident that the 2017 RCP addresses most of the remaining higher classified risk statements, particularly from categories that were not evaluated in the 2017 workshop. For example, the highest classified risks in this table relate to consequences from a general failure to conduct preventative maintenance and corrective actions leading to system failures. The likelihood of these failures was rated as 'LIKELY' in 2014 on the basis of the duration of post-closure monitoring and maintenance in RCP 2014-01. RCP v2017-01 includes a plan and a closure (security) cost allowance for a much longer PCMM duration.

3.4 PARKING LOT ITEMS

The 2014 issues raised that were recorded in the Parking Lot were itemized previously in Section 1.2. They are reproduced again below with an indication of how each item was addressed in RCP v2017-01 and/or the 2017 FMEA.

- **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;**

  The designs for final reclaimed facilities have been advanced substantially in RCP v2017-01, and the final re-grading plans for the waste facilities were also available for the 2017 FMEA and will be included in RCP v2018-01.

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

  RCP v2017-01 included additional information regarding the RRP, particularly related to the Constructed Wetland Treatment System research. RCP v2018-01 further updates work on this research component (Section 2.2) and the accompanying cover design report (Updated Closure Cover Design for the Minto Mine 2018 Reclamation and Closure Plan (SRK Consulting, January 2018)) incorporates recommendations based on observations of the Main Waste Dump revegetation trials during inspections carried out during July 2017.

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

  The Ridgetop Pits were not a part of the mine plan that underpinned RCP v2017-01. Now that the Ridgetop pits have been re-integrated into the mine plan, a trafficability layer over the Ridgetop North Pit tailings backfill has been added to the mitigative measures for that facility in RCP v2018-01.

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

  RCP v2017-01 presented the documentation of the systematic process that was undertaken to identify and select appropriate passive treatment technologies for the Minto Site. The RCP also presented a detailed design for the installation of a constructed wetland treatment system as part of the closure configuration, with associated *monitoring, maintenance and adaptive management plans to ensure its efficacy in the post-closure period. The system was evaluated in depth in the Water Treatment topic in the 2017 FMEA workshop, which included a select group of technical experts who were responsible for the treatment system design.*

- **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**

  This consequence category was not included in the 2017 workshop exercise.

- **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.**

  This issue has not been addressed in any RCP updates. It continues to be a future land use management decision requiring resolution with SFN.

4. SUMMARY

The risk registers updated during the 2017 FMEA workshops are provided in Appendix B and the risk matrices, both the initial (RCP v2017-01) and re-ranked (including proposed mitigations in RCP v-2018-01), are provided in Appendix C.

Although some risk consequence categories utilized in previous FMEA sessions were not included in this exercise, previous risk entries were evaluated in a more detailed fashion, leading to more registry entries than in the 2014 exercise. A more detailed and developed RCP, including a detailed plan for construction and operation of a passive treatment installation, allowed a fulsome evaluation of detailed risk statements, including risks and consequences of failure of the passive water treatment system. The 2017 FMEA addressed items from the 2014 FMEA 'Parking Lot'.

Overall, the exercise returned mostly 'low' and 'moderate' risks associated with the v2017-01 plan. The unacceptable risk areas (high and very-high) contained only three entries. Two of the three were Administrative risk/consequence statements that were not changed from 2014 (although the 2017 workshop team strongly disagrees with the previous risk rating). Further, the 2017 team suggests that the risk has either been mitigated since 2014 (with additional financial security posted with YG) or there is no conceivable way to mitigate the risk, as it assumes violation of future licence conditions. Both entries are of the Cost Consequence category.

The third unacceptable risk statement regarding a failure to relocate SAT material prior to completion of the Main Pit Dump (as with some others) was subject to a 're-ranking' after the identification of additional mitigation measures, which reduced the risk classification from 'very high' to 'low'.

APPENDIX A.
Risk Rating Tools

Consequence-Severity Matrix

Consequence Categories	Severity Descriptors: Very Low	Minor	Moderate	Major	Critical
1. **Environmental Impact (EI)**	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. **Consequence Costs (CC)**	< $100,000	$100,000 - $500,000	$ 500,000 - $2.5 Million	$2.5-$10 Million	>$10 Million
3. **Human Health and Safety (HHS)**	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.

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

APPENDIX B.
2017 FMEA Risk Registers

TABLE B-1: Open Pits Risk Register

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Risk
Low
Moderate
Moderately High
High
Very High

Open Pits (P)											Mitigated		
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING		CLASSIFICATION	changed?	COMMENTS	Potential Mitigations	RISK RATING		CLASSIFICATION
					L	C					L	C	
P1	Area 2 Pit	Precipitation higher than design asssumption (1:200 yr 24 hr)	Damage to outlet structure	CC	Unlikely	Very Low	Low	Y	Assumes earthwork repairs to spillway Plan includes cost allocation for regular maintenance				
P2	Area 2 Pit	Precipitation higher than design asssumption (1:200 yr 24 hr)	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	EI				Y	no Main Dam, not relevant				
P3	Area 2 Pit	Precipitation higher than design asssumption (1:200 yr 24 hr)	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	CC				Y	no Main Dam, not relevant				
P4	Area 2 Pit	Precipitation higher than design asssumption (1:200 yr 24 hr)	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	HHS				Y	no Main Dam, not relevant				
P5	Area 2 Pit	Pit wall failure in Area 2	Wave of water released from pit causing damage to downstream facilities (ditches, passive treatment system, covers)	EI	Very Unlikely	Moderate	Low	Y	Large degree of uncertainty regarding the likelihood of failure duration limited to 'seconds' A2 Pit outflow would not pass all of wave, wave would disperse down conveyance, high flow bypass would protect wetlands				
P6	Area 2 Pit	Pit wall failure in Area 2	Wave of water released from pit causing damage to downstream facilities (ditches, passive treatment system, covers)	CC	Very Unlikely	Moderate	Low	Y	includes significant repairs to all downstream structures, including CWTS				
P7	Area 2 Pit	Pit wall failure in Area 2	Wave of water released from pit and causes a fatality.	HHS	Very Unlikely	Critical	Moderately High	N	Same as above; -Ranking preliminary; Failure has not been evaluated. -If a lower likelyhood option was available, it would have been selected.				
P8	Area 2 Pit	Ongoing overburden south wall erosion (A2S3) from either wave action or runoff	sediment deposition in downstream conveyance structures leading to increased maintenance requirements beyond those planned	CC	Unlikely	Minor	Low	NEW	assumes mitigation by armouring would be implemented				
P9	Area 2 Pit	Ongoing overburden south wall erosion (A2S3) from either wave action or runoff	sediment deposition in downstream conveyance structures leading to unacceptable TSS concentrations in site discharge	EI	Unlikely	Minor	Low	NEW	TSS settlment in pit would mitigate most of this potential				
P10	Area 2 Pit	Pit water quality degraded unacceptably (dissolved constituents)	Unacceptable water quality conditions for water fowl / wildlife	EI	Very Unlikely	Moderate	Low	Y	Scenario was evaluated (Minnow)				
P11	Minto North Pit	Positive water balance for pit	Overtopping or piping and erosion at spill point and sediment release downstream, causing unacceptable sedimentation in Mcginty Creek	EI	Unlikely	Minor	Low	N	This is included in Closure AMP. Observations during operations and Post-closure 1 period will be useful in better understanding future fate of MN Pit water balance				
P12	Minto North Pit	Massive rapid pit wall failure into pit full of water	Wave of water spilling over rim of pit causing erosion and downstream sedimentation and riparian damage	EI	Unlikely	Minor	Low	Y	consideration was given to the fact that there has already been a pit wall failure in Minto North pit, so likelihood of combined failure mode and consequence was changed from very unlikely to unlikely				
P13	Minto North Pit	Pit wall failure	Causes a fatality.	HHS	Very Unlikely	Critical	Moderately High	NEW	mitigated by SWP for monitoring in pit				
P14	Ridgetop North Pit	Erosion of downstream slope due to runoff from covered tailings	Need for repairs	CC	Possible	Minor	Moderate	N	Could be mitigated through AMP or addressed in closure plan	add route for surface water drainage	Very Unlikely	Very Low	Low
P15	Ridgetop North Pit	Settlement of tailings	Ponding on surface of covered tailings resulting in increased infiltration and leading unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	N					
P16	Ridgetop North Pit	High wall slope failure	Cover damage, exposure of tailings and need for cover repairs	CC	Possible	Very Low	Low	Y	pit wall failures have been observed on site, but cost of repairs are modest				
P17	Ridgetop North Pit	Seepage of water within RNPTMF against E/NE overburden wall	Slope instability in overburden in A2S3 and need for repairs	CC	Possible	Very Low	Low	Y	conservative slope stability analysis to evaluate risk of this failure mode was undertaken, possible sloughing in short term, repairs are modest				
P18	Ridgetop North Pit	Thawing of entrained ice in tailings	Cover damage, exposure of tailings and need for cover repairs	CC	Possible	Moderate	Moderately High	NEW		will be mitigated through appropriate tailings deposition plan	Very Unlikely	Moderate	Low

TABLE B-1: Open Pits Risk Register

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Risk
Low
Moderate
Moderately High
High
Very High

Open Pits (P)											Mitigated		
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING L	RISK RATING C	CLASSIFICATION	changed?	COMMENTS	Potential Mitigations	RISK RATING L	RISK RATING C	CLASSIFICATION
P19	Ridgetop North Pit	Thawing of entrained ice in tailings leads to ponding and saturation	Slope instability in overburden in A2S3 and need for repairs	CC	Unlikely	Very Low	Low	Y	conservative slope stability analysis to evaluate risk of this failure mode was undertaken, possible sloughing in short term, repairs are modest				
P20	Ridgetop North Pit	piping of tailings material or internal erosion of OVB below RTNTF	instability and uncontrolled release of tailings and unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	NEW	scenario was assessed in response to information request during YWB review of Phase V/VI Expansion Project				
P21	Ridgetop North Pit	piping of tailings material through cover results in 'boils' of exposed tailings	need for repairs/clean up of exposed tailings	CC	Unlikely	Very Low	Low	NEW					
P22	Main Pit	Precipitation higher than design asssumption (1:200 yr 24 hr)	Damage to outlet structure	CC	Unlikely	Very Low	Low	NEW	Assumes earthwork repairs to spillway Plan includes cost allocation for regular maintenance				
P23	Main Pit	Pit wall failure	Wave of water released from pit causing damage to downstream facilities (ditches, passive treatment system, covers)	CC	Very Unlikely	Minor	Low	NEW	assuming less than 2m of water cover, so 'wave potential' not the same as A2 pit, lower volume of water, less damage downstream				
P24	Main Pit	Pit wall failure	Wave of water released from pit causing damage to downstream facilities (ditches, passive treatment system, covers)	EI	Very Unlikely	Moderate	Low	NEW					
P25	Main Pit	Pit water quality degraded unacceptably (dissolved constituents)	Unacceptable water quality conditions for water fowl / wildlife	EI	Very Unlikely	Moderate	Low	NEW	Scenario was evaluated (Minnow)				
P26	Main Pit	Wind suspension of tailings mobilizes tailings material out of MPTMF	sediment deposition in downstream conveyance structures leading to increased maintenance requirements beyond those planned	CC	Very Unlikely	Moderate	Low	NEW	Traffic surface element of tailings suface cover will extend below final water elevation to mitigate wind wave turbulence circle suspending tailings				
P27	Main Pit	piping of tailings material through cover results in 'boils' of exposed tailings	need for repairs/clean up of exposed tailings	CC	Possible	Very Low	Low	NEW					

TABLE B-2: DSTSF Risk Register

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Dry Stack Tailings Storage Facility (T)											Mitigated		
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING		CLASSIFICATION	changed?	COMMENTS	Potential Mitigations	RISK RATING		CLASSIFICATION
					L	C					L	C	
T1	DSTSF/MVFE	Long-term permafrost degradation underlying the DSTSF leads differential settlement and ponding of water resulting in increased infiltration leading to	Unacceptable downstream water quality	EI	Unlikely	Minor	Low	N					
T2	DSTSF/MVFE	Long-term permafrost degradation underlying the DSTSF leads to differential settlement and ponding of water	Need for repair	CC	Possible	Minor	Moderate	N					
T3	DSTSF/MVFE	Long-term permafrost degradation underlying the DSTSF leads differential settlement and ponding of water	Erosion of cover materials and sediment loading to passive treatment system	EI	Possible	Minor	Moderate	N	Maintenance issue				
T4	DSTSF/MVFE	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 and increased infiltration	Impacts to downstream water quality.	EI	Very Unlikely	Minor	Low	N	Mitigated by construction of MVFE S2				
T5	DSTSF/MVFE	Deep-seated downvalley slope failure of the MVFE (Section F)	Instability of the DSTSF and cracking of the cover, failure of conveyance ditches and need for additional stabilization measures.	CC	Very Unlikely	Major	Moderate	N	MVFE S2 design report calculates a minimum FOS of 2.3. MVFE S2 has been constructed years before closure, and will continue to produce years of performance monitoring data. No significant concerns with down valley movement with one year of data.				
T6	DSTSF/MVFE	MVFE S2 does not extend far enough downvalley	Cross-valley movement at the eastern extent of the current movement affecting the DSTSF and need for additional stabilization measures.	CC	Very Unlikely	Major	Moderate	NEW	MVFE S2 has been constructed years before closure, and will continue to produce years of performance monitoring data. No significant concerns with down valley movement with one year of data.				
T7	DSTSF/MVFE	Toe failure of the MVFE	Instability and cracking of the cover, failure of conveyance ditches and need for additional stabilization measures.	CC	Unlikely	Minor	Low	Y	Facility is constructed, and no concerns based on performance data.				
T8	DSTSF/MVFE	Toe failure of the MVFE	failure of conveyance ditch and mobilization of sediment, leading to unacceptable TSS concentrations in site discharge	EI	Very Unlikely	Minor	Low	NEW	Facility is constructed, and no concerns based on performance data.				
T9	DSTSF/MVFE	Movement (lateral movement or differential settlement) reduces or blocks flow from the finger drains underlying the DSTSF	Increased pore pressure within tailings mass, raising of water table within tailings mass and ultimately increased daylighting of groundwater upgradient of DSTSF	EI	Very Unlikely	Minor	Low	N					
T10	DSTSF/MVFE	Facility instability results in waste material exposure to water and reduced cover performance	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	NEW					
T11	DSTSF/MVFE	Erosion on slopes leads to loss of cover	Need for repairs beyond regular maintence planned	CC	Unlikely	Minor	Low	NEW					
T12	DSTSF/MVFE	Die-back of cover vegetation after successful establishment and acceptance leads to erosion	Need for repairs beyond regular maintence planned	CC	Unlikely	Minor	Low	NEW					
T13	DSTSF/MVFE	Root throw results in increased infiltration over the long term	Need for repairs beyond regular maintence planned	CC	Unlikely	Minor	Low	NEW					

TABLE B-3: Waste Rock Dump Risk Register

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Risk
Low
Moderate
Moderately High
High
Very High

Waste Rock Dumps (D)											Mitigated		
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING		CLASSIFICATION	changed?	COMMENTS	Potential Mitigations	RISK RATING		CLASSIFICATION
					L	C					L	C	
D1	Main Waste Dump	Run-on water from upgradient catchment of MWD increases flow subsurface and contaminant loading from waste rock	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	N	MWD has limited upgradient catchment area and limited resulting run-on				
D2	Main Waste Dump	Ponding of water on surface of MWD leads to excessive infiltration, increases flow subsurface and contaminant loading from waste rock	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	Y	has been mitigated by shaping surface to limit ponding				
D3	Main Waste Dump	Instability results in waste material exposure to water	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	N	Likelihood supported by stability evaluations in MWDE design report				
D4	Main Waste Dump	Erosion on steeper portion of MWD leads to loss of cover	Need for repairs beyond regular maintence planned	CC	Almost Certain	Minor	Moderately High	Y	has been observed at site on this facility	Waste Rock wrap at toe to reduce slope of bottom of slopes	Unlikely	Minor	Low
D5	Main Waste Dump	Die-back of cover vegetation after successful establishment and acceptance leads to erosion	Need for repairs beyond regular maintence planned	CC	Possible	Minor	Moderate	N	MWD has 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. Three additional years of monitoring observations of MWD revegetation trials have not shown any signs of die-back, however likelihood was kept the same.				
D6	Main Waste Dump	Root throw results in increased infiltration over the long term	Need for repairs beyond those planned	CC	Unlikely	Minor	Low	N					
D7	Southwest Waste Dump	Run-on water from upgradient catchment of SWD increases flow subsurface and contaminant loading from waste rock	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	N	SWD has limited upgradient catchment area and limited resulting run-on				
D8	Southwest Waste Dump	Ponding of water on surface of SWD leads to excessive infiltration, increases flow subsurface and contaminant loading from waste rock	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	Y	Requires failure of AMP to realize the scenario. Reclamation plan now includes shaping surface to limit ponding - likelihood reduced; 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				
D9	Southwest Waste Dump	Instability results in cover compromised and waste material exposure to water	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	N	Likelihood supported by stability evaluations in SWD design report. Foundation includes permafrost overburden, but the design considered the existing foundation conditions.				
D10	Southwest Waste Dump	Instability results in cover compromised	Need for repairs beyond regular maintence planned	CC	Unlikely	Very Low	Low	NEW	Planned maintenance most likely to cover this type of repair work.				
D11	Southwest Waste Dump	Erosion on steeper portions of SWD leads to loss of cover	Need for repairs beyond regular maintence planned	CC	Unlikely	Minor	Low	Y	Likelihood can be reduced through implementation of design, including planned vegetation, and planned maintenance is most likely to cover this type of repair work.				
D12	Southwest Waste Dump	Die-back of cover vegetation after successful establishment and acceptance leads to erosion	Need for repairs beyond regular maintence planned	CC	Possible	Minor	Moderate	N	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. Expect experience from MWD to be replicated.				
D13	Southwest Waste Dump	Root throw results in increased infiltration over the long term	Need for repairs beyond regular maintence planned	CC	Unlikely	Minor	Low	N					
D14	Southwest Waste Dump	Root throw results in damage to engineered cover (BGM) over HGW leads to increased infiltration over the long term	Need for repairs beyond regular maintence planned	CC	Possible	Minor	Moderate	N		HGW will be removed prior to closure, area treated similar to rest of SWD facility, therefore this risk is eliminated (not ranked.)			
D15	Ridgetop Waste Dump	Run-on water from upgradient catchment of RWD increases flow subsurface and contaminant loading from waste rock	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	N	MWD has limited upgradient catchment area and limited resulting run-on				
D16	Ridgetop Waste Dump	Ponding of water on surface of MWD leads to excessive infiltration, increases flow subsurface and contaminant loading from waste rock	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	Y	has been mitigated by shaping surface to limit ponding				
D17	Ridgetop Waste Dump	Instability results in waste material exposure to water	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	N	Likelihood supported by stability evaluations in MWDE design report				
D18	Ridgetop Waste Dump	Erosion on steeper portion of MWD leads to loss of cover	Need for repairs beyond regular maintence planned	CC	Possible	Minor	Moderate	N	Can be mitigated through design and/or O&M plan				

TABLE B-3: Waste Rock Dump Risk Register

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Risk
Low
Moderate
Moderately High
High
Very High

Waste Rock Dumps (D)											Mitigated		
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING L	RISK RATING C	CLASSIFICATION	changed?	COMMENTS	Potential Mitigations	RISK RATING L	RISK RATING C	CLASSIFICATION
D19	Ridgetop Waste Dump	Die-back of cover vegetation after successful establishment and acceptance leads to erosion	Need for repairs beyond regular maintence planned	CC	Possible	Minor	Moderate	N	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				
D20	Ridgetop Waste Dump	Root throw results in increased infiltration over the long term	Need for repairs beyond those planned	CC	Unlikely	Minor	Low	N					
D21	Reclamation OVB, Ridgetop South & Area 118 Backfill Dumps	Run-on water from upgradient catchments increases flow subsurface and contaminant loading from overburden	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	N	Dump contents are overburden				
D22	Reclamation OVB, Ridgetop South & Area 118 Backfill Dumps	Thawing of ice-rich OVB leads to settlement and ponding of water on surface of overburden dumps leads to excessive infiltration, increases flow subsurface and contaminant loading from overburden	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	N	Designs of A118 and RS BD are mounded to shed water.				
D23	Reclamation OVB, Ridgetop South & Area 118 Backfill Dumps	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	Need for development of channel	CC	Very Unlikely	Minor	Low	N	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				
D24	Reclamation OVB, Ridgetop South & Area 118 Backfill Dumps	Die-back of re-vegetation after successful establishment and acceptance leads to erosion	Need for repairs beyond regular maintence planned	CC	Unlikely	Very Low	Low	Y	No requirement to maintain cover integrity due to dump material (OVB); have observed natural revegetation on portions of ROD				
D25	Site Wide - Covers	Burrowing animals burrow in covers, increasing infiltration	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	NEW					
D26	Site Wide - Covers	Burrowing animals burrow in covers and/or trail footprints leading to erosion	Need for repairs beyond regular maintence planned	CC	Very Unlikely	Minor	Low	NEW					
D27	Main Pit Dump/SAT Dump	SAT material is not relocated prior to completion of Main Pit Dump,	portion of MPD needs to be excavated for SAT material relocation	CC	Almost Certain	Major	Very High	NEW		Main Pit Dump **has been revised** to not cover SAT material, and construction is underway	Very Unlikely	Very Low	Low
D28	Main Pit Dump/SAT Dump	Construction of MPD leads to re-activation of South Wall shear zone and failure of SouthWall/MPD into Main Pit	need for re-stabilization and repairs to cover and conveyance channels	CC	Very Unlikely	Major	Moderate	NEW					
D29	Main Pit Dump/SAT Dump	Erosion on steeper portion of MWD leads to loss of cover	Need for repairs beyond regular maintence planned	CC	Possible	Minor	Moderate	NEW	Can be mitigated through design and/or O&M plan				
D30	Main Pit Dump/SAT Dump	Die-back of cover vegetation after successful establishment and acceptance leads to erosion	Need for repairs beyond regular maintence planned	CC	Possible	Minor	Moderate	NEW	MPD 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				
D31	Main Pit Dump/SAT Dump	Root throw results in increased infiltration over the long term	Need for repairs beyond those planned	CC	Unlikely	Minor	Low	NEW					

TABLE B-4: Water Conveyance Structure Risk Register

Minto Explorations Ltd.

Minto Mine

FAILURES MODES AND EFFECTS ASSESSMENT

Risk
Low
Moderate
Moderately High
High
Very High

Water Conveyance (W)											Mitigated		
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING L	RISK RATING C	CLASSIFICATION	changed?	COMMENTS	Potential Mitigations	RISK RATING L	RISK RATING C	CLASSIFICATION
W1	Ditch A	Instability of the MPD or South Wall compromises Ditch A leads to exposure of waste rock and infiltration	Unacceptable water quality downstream	EI	Very Unlikely	Minor	Low	Y	Channel no longer runs on top of MPD				
W2	Ditch A	Instability of the MPD or South Wall compromises Ditch A	Repair requirements	CC	Very Unlikely	Minor	Low	Y					
W3	Ditch A	thaw consolidation of permafrost overburden in South Wall leads to deformation of Ditch A	Repair requirements	CC	Very Unlikely	Very Low	Low	NEW	Design tolerates thaw consolidation				
W4	Ditch A	Flows exceed Ditch A capacity resulting in failure of water conveyance structures	Repair requirements	CC	Very Unlikely	Very Low	Low	NEW	Alignment follows new valley bottom landform				
W5	Ditch B	Thaw degradation leads to retrogressive failure at inlet of A2S3 Pit	Need for repairs beyond regular maintenance already planned	CC	Likely	Moderate	Moderately High	NEW	2016 design does not account for consequences of long term thaw	cost allowance for design of improved inlet structure	Unlikely	Minor	Low
W6	Ditch B	Thaw degradation leads to retrogressive failure at inlet of A2S3 Pit	sediment deposition in downstream conveyance structures leading to unacceptable TSS concentrations in site discharge	EI	Unlikely	Minor	Low	NEW	TSS settlment in pit would mitigate most of this potential				
W7	Ditch B	Flows exceed Ditch B capacity resulting in failure of water conveyance structure and flows over DSTSF leading to cover damage	Repair requirements	CC	Very Unlikely	Moderate	Low	NEW		DSTSF Landform design includes regrading to direct flows around DSTSF rather than over	Very Unlikely	Minor	Low
W8	TDD	Extreme event leads to failure of TDD conveyance structure upgradient of DSTSF, flow onto DSTSF leading to cover damage	Repair requirements	CC	Very Unlikely	Minor	Low	NEW	discussion considered whether tailings could be mobilized, was decided not likely enough to consider				
W9	TDD	Leakage from TDD conveyance structure upgradient of DSTSF increases flow subsurface and contaminant loading from tailings	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	Y	updgraded TDD constructed				
W10	Primary Channels	Winter ice development in channels causes freshet flows to be above protected elevations, leading to erosion	Need for repairs beyond regular maintenance already planned	CC	Likely	Minor	Moderate	Y	May be a reccuring event. Risk is lower where foundation is mine fill. Candidate locations could be mitigated with additional erosion protection.				
W11	Ditch C	Thaw degradation leading to differential settlment of channel/inlet	Need for repairs	CC	Possible	Very Low	Low	NEW					
W12	Ditch C	Flows exceed Ditch C level of erosion protection resulting in damage to inlet structure/ditch and mobilization of tailings downstream	cleanup and Repair requirements	CC	Very Unlikely	Major	Moderate	NEW					
W13	Ditch C	Flows exceed Ditch C level of erosion protection resulting in damage to inlet structure/ditch and mobilization of tailings downstream	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	NEW					
W14	Ditch C	Failure of Main Pit north wall blocks inlet to Ditch C, leading to backing up of water and sudden release of water into Ditch C, damaging conveyance structure	Need for repairs	CC	Unlikely	Minor	Low	NEW					
W15	Ditch D	Thaw degradation leading to differential settlement of Channel in Ditch D	Need for repairs	CC	Very Unlikely	Very Low	Low	Y	large cut of Channel D lowers likelihood				
W16	Ditch D	Thaw degradation leading to differential settlement in Ditch D leading to ponding, overtopping, and erosion	Need for repairs	CC	Very Unlikely	Minor	Low	Y	large cut of Channel D lowers likelihood				
W17	Ditch D	Flows exceed Ditch D capacity resulting in failure of water conveyance structures	Repair requirements	CC	Very Unlikely	Very Low	Low	NEW					
W18	Ditch D	Channel side slope failure blocks inlet to Ditch D, leading to backing up of water in A2 Pit and sudden release of water into Ditch D, damaging conveyance structure	Need for repairs	CC	Very Unlikely	Minor	Low	NEW	Cut mostly in waste rock, potential for failure low				

TABLE B-4: Water Conveyance Structure Risk Register

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Risk
Low
Moderate
Moderately High
High
Very High

Water Conveyance (W)											Mitigated		
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING L	RISK RATING C	CLASSIFICATION	changed?	COMMENTS	Potential Mitigations	RISK RATING L	RISK RATING C	CLASSIFICATION
W19	Ditch E	Flows exceed Ditch E capacity resulting in failure of water conveyance structures and erosion of MVFE cover, mbilization of sediments into CWTS head pond	Repair requirements for cover and ditch and cleanout of sediments in CWTS head pond	CC	Very Unlikely	Minor	Low	NEW					
W20	Ditch E	Thaw degradation leading to differential settlement in Ditch D leading to ponding, overtopping, and erosion	Need for repairs	CC	Very Unlikely	Minor	Low	NEW	potential for thaw consolidation in this area is less than that which would lead to overtopping of ponded water in Ditch E				
W21	Ditch E	Thaw degradation leading to differential settlement in Ditch E leading to ponding, overtopping and erosion resulting in sediment loading into passive treatment system	Unacceptable water quality conditions downstream of site	EI	Very Unlikely	Moderate	Low	N					
W22	CWTS High Flow Bypass	Landslide dam forms in CWTS high flow bypass channel as a result of thawing of permafrost overburden in S valley wall	Impounding of water and subsequent rapid breach and sediment loading downstream	EI	Possible	Minor	Moderate	Y	Included in post-closure monitoring - geotechnical inspections				
W23	CWTS High Flow Bypass	Landslide dam forms in CWTS high flow bypass channel as a result of thawing of permafrost overburden in S valley wall	Impounding of water and subsequent rapid breach and sediment loading downstream and need for repairs of conveyance and possibly slope	CC	Possible	Minor	Moderate	NEW					
W24	CWTS High Flow Bypass	Blockage forms in CWTS high flow bypass channel from woody debris (beaver/fallen trees)	Impounding of water and subsequent diversion into wetland causing damage to CWTS	CC	Possible	Minor	Moderate	NEW					
W25	Primary Channels	Inadequate design of primary network	Need for repairs	CC				Y	To broad to be useful, risks are addressed on specific feature basis.				
W26	Primary Channels	Flows exceed channel capacity resulting in failure of water conveyance structures	Need for repairs	CC				Y	To broad to be useful, risks are addressed on specific feature basis.				
W27	Secondary Channels	Excessive concentrated flows lead to erosion and gulley formation and mass wasting	Unacceptable sediment load downstream	EI	Unlikely	Minor	Low	Y	secondary channels are designed/armoured, erosion potential low				
W28	Secondary Channels	Excessive concentrated flows lead to erosion and gulley formation leading to waste rock exposure and infiltration	Unacceptable water quality downstream	EI	Unlikely	Moderate	Moderate	Y	changed to unlikely to reflect chance of moderate scale consequence, and moderate to be consistent with previous consequence rankings	advancements in design, progress on regrading at site	Very Unlikely	Moderate	Low
W29	Secondary Channels	Excessive concentrated flows lead to erosion and gulley formation	Repair requirements	CC	Unlikely	Very Low	Low	Y	Requires greater than design criteria flows to be any more than unlikely, sheet erosion analysis has been undertaken; site presence in PC will ensure site presence when these repairs are most likely required				
W30	Secondary Channels	Inadequate design of secondary network	Need for repairs	CC	Unlikely	Very Low	Low	Y	secondary network now designed for 1:200 yr event; site presence in PC will ensure site presence when these repairs are most likely required				
W31	Secondary Channels	Thaw consolidation near DSTSF leading to differential settlement under channel leading to ponding, overtopping, and erosion/tailings mobilization	Unacceptable water quality downstream	EI	Very Unlikely	Moderate	Low	NEW	Rating assumed erosion on South side where no rock shell exists				
W32	Secondary Channels	Thaw consolidation near DSTSF leading to differential settlement under channel leading to ponding, overtopping, and erosion/tailings mobilization	repairs required beyond regular maintenance	CC	Possible	Minor	Moderate	NEW	Rating assumed erosion on South side where no rock shell exists	refine landform design to reduce length of individual secondary channels and associated catchment areas	Very Unlikely	Minor	Low
W33	Tertiary Channels	Differential settlement leading to excessively concentrated flows in channels	scour and erosion and filling of the energy dissipator structures	CC	Unlikely	Minor	Low	Y	These networks are typically on flatter areas, which cannot generate velocities required for substantial erosion. Requires greater than design criteria flows to be any more than unlikely, sheet erosion analysis has been undertaken; site presence in PC will ensure site presence when these repairs are most likely required				

TABLE B-4: Water Conveyance Structure Risk Register

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Risk
Low
Moderate
Moderately High
High
Very High

Water Conveyance (W)											Mitigated		
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING L	RISK RATING C	CLASSIFICATION	changed?	COMMENTS	Potential Mitigations	RISK RATING L	RISK RATING C	CLASSIFICATION
W34	Tertiary Channels	Differential settlement leading to excessively concentrated flows in channels leading to waste rock exposure and infiltration	Unacceptable water quality downstream	EI				Y	removed: see WRD rankings				
W35	Tertiary Channels	Differential settlement leading to excessively concentrated flows in channels leading to waste rock exposure and infiltration	Repair requirements	CC				Y	removed: see WRD rankings				
W36	Tertiary Channels	Inadequate design of tertiary network	Need for repairs	CC	Unlikely	Minor	Low	Y	have completed erosion analysis with has illustrated low sensitivity to design details. Adequate vegetation cover is most important measure to adequately control erosion. site presence in PC will ensure site presence when these repairs are most likely required				
W37	Tertiary Channels	Vegetation growth is less than expected leading to concentrated flows, erosion and sedimentation of downstream conveyance structures	need for cleanup/repairs	CC	Unlikely	Minor	Low	Y	Risk mitigated through existing plan for periodic maintenance and in Closure AMP. Landform design has been advanced				

TABLE B-5: Administrative Risk Register

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Administrative (A)										
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING		CLASSIFICATION	changed?	COMMENTS
					L	C			
A1	Site Wide	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.)	Impacts on ecosystem components	EI	Unlikely	Major	Moderately High	Y	Cost allowance now included for long term monitoring and maintenance activities, and facility design improvements have reduced exposure to risk.
A2	Site Wide	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.)	* undefined *	CC				N	Not rated in 2014, revisited, still no definable cost associated with this.
A3	Site Wide	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.)	H&S impacts	HHS	Unlikely	Minor	Low	N	
A4	Site Wide	Departure from design of engineered structures during construction	Unacceptable water quality conditions downstream	EI	Possible	Moderate	Moderately High	N	This ranking assumes violation of future licence conditions that authorize construction of engineered structures, and failure of regulatory oversight during/following construction. Will be mitigated with appropriate QA/QC monitoring, as per standard construction practice. 2017 Participants strongly disagree with this risk rating (from 2014 workshop) as it is based on future dicision-making, but it has not been changed as there are no conceivable current ways to mitigate this risk.
A5	Site Wide	Departure from design of engineered structures	Need for upgrades/ repairs/ redesign	CC	Possible	Major	High	N	This ranking assumes violation of future licence conditions that authorize construction of engineered structures, and failure of regulatory oversight during/following construction. Will be mitigated with appropriate QA/QC monitoring, as per standard construction practice. 2017 Participants strongly disagree with this risk rating (from 2014 workshop) as it is based on future decision-making, but it has not been changed as there are no conceivable current ways to mitigate this risk.
A6	Site Wide	Bankruptcy/ dissolution of the company and inadequate financial security	Requirement for public government to fund and conduct preventative maintenance and corrective actions to avoid system failures and impacts on ecosystem components	CC	Possible	Major	High	N	Likelihood rating was initially selected (2014) to reflect that this scenario has happened elsewhere. The 2017 participants strongly disagree with the 2014 risk ranking, as there has been a substantial increase in financial security. However, the risk ranking has not been changed.
A7	Site Wide	Failure of institutional controls	Land use that causes unanticipated negative exposure of humans or wildlife	HHS	Very Unlikely	Critical	Moderately High	N	Rated assuming failure results in a human fatality. Likelihood rating considers remoteness of site. Access to site in post closure remains a future land-use management decision requiring resolution. Risk ranking not changed in 2017.
A8	Site Wide	Failure of quality control during cover construction results in use of overburden materials that do not meet specifications	revegetation objectives not being achieved and additional work required to replace portions of cover	CC	Very Unlikely	Major	Moderate	NEW	ranking assumes example of full replacement of cover on DSTSF

TABLE B-6: Water Treatment Risk Register

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Water Treatment (WT)											Mitigated		
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING		CLASSIFICATION	changed?	COMMENTS	Additional Potential Mitigations	RISK RATING		CLASSIFICATION
					L	C					L	C	
WT1	Source Terms	Waste rock upgradient of pits has source water quality worse than predicted, resulting in increased concentrations in pit lakes and in CWTS influent, and increased loadings in CWTS effluent	significant impact to downstream aquatic resources	EI	Unlikely	Moderate	Moderate	Y	assumes AMP is followed				
WT2	Source Terms	Waste rock upgradient of pits has source water quality worse than predicted, resulting in increased concentrations in pit lakes and in CWTS influent, and increased loadings in CWTS effluent	minor localized or short-term impacts to downstream aquatic resources	EI	Unlikely	Minor	Low	NEW	assumes AMP is followed				
WT3	Source Terms	Waste rock upgradient of pits has source water quality worse than predicted, resulting in increased concentrations in pit lakes and in CWTS influent, and increased loadings in CWTS effluent	resulting in implementation of mitigation measures	CC	Unlikely	Critical	Moderately High	N	assumes implementation of responses in AMP lead to long term active water treatment				
WT4	Source Terms	Pit walls have source water quality worse than predicted, resulting in increased concentrations in pit lakes and in CWTS influent, and increased loadings in CWTS effluent	significant impact to downstream aquatic resources	EI	Unlikely	Moderate	Moderate	NEW	assumes AMP is followed				
WT5	Source Terms	Pit walls have source water quality worse than predicted, resulting in increased concentrations in pit lakes and in CWTS influent, and increased loadings in CWTS effluent	minor localized or short-term impacts to downstream aquatic resources	EI	Unlikely	Minor	Low	NEW	assumes AMP is followed				
WT6	Source Terms	Pit walls have source water quality worse than predicted, resulting in increased concentrations in pit lakes and in CWTS influent, and increased loadings in CWTS effluent	resulting in implementation of mitigation measures	CC	Unlikely	Moderate	Moderate	NEW	assumes implementation of responses in AMP				
WT7	Source Terms	In-pit tailings has source water quality worse than predicted, resulting in increased concentrations in pit lakes and in CWTS influent, and increased loadings in CWTS effluent	significant impact to downstream aquatic resources	EI	Unlikely	Moderate	Moderate	NEW	assumes AMP is followed				
WT8	Source Terms	In-pit tailings has source water quality worse than predicted, resulting in increased concentrations in pit lakes and in CWTS influent, and increased loadings in CWTS effluent	minor localized or short-term impacts to downstream aquatic resources	EI	Unlikely	Minor	Low	NEW	assumes AMP is followed				
WT9	Source Terms	In-pit tailings has source water quality worse than predicted, resulting in increased concentrations in pit lakes and in CWTS influent, and increased loadings in CWTS effluent	resulting in implementation of mitigation measures	CC	Unlikely	Moderate	Moderate	NEW	assumes implementation of responses in AMP				
WT10	Source Terms	Dry Stack tailings has source water quality worse than predicted, resulting in increased concentrations in CWTS influent, and increased loadings in CWTS effluent	significant impact to downstream aquatic resources	EI	Unlikely	Moderate	Moderate	NEW	assumes AMP is followed				
WT11	Source Terms	Dry Stack tailings has source water quality worse than predicted, resulting in increased concentrations in CWTS influent, and increased loadings in CWTS effluent	minor localized or short-term impacts to downstream aquatic resources	EI	Possible	Minor	Moderate	NEW	assumes very short duration, i.e. failure mode is an ice blockage at the toe of the MFVE that impounds seepage and then melts in spring, resulting in a quick drainage of impounded water				
WT12	Source Terms	Dry Stack tailings has source water quality worse than predicted, resulting in increased concentrations in CWTS influent, and increased loadings in CWTS effluent	resulting in implementation of mitigation measures	CC	Unlikely	Critical	Moderately High	N	assumes implementation of responses in AMP lead to long term active water treatment				
WT13	Source Terms	MVFE has source water quality worse than predicted, resulting in increased concentrations in CWTS influent, and increased loadings in CWTS effluent	significant impact to downstream aquatic resources	EI	Unlikely	Moderate	Moderate	NEW	assumes AMP is followed				
WT14	Source Terms	MVFE has source water quality worse than predicted, resulting in increased concentrations in CWTS influent, and increased loadings in CWTS effluent	minor localized or short-term impacts to downstream aquatic resources	EI	Unlikely	Minor	Low	NEW	assumes AMP is followed				
WT15	Source Terms	MVFE has source water quality worse than predicted, resulting in increased concentrations in CWTS influent, and increased loadings in CWTS effluent	resulting in implementation of mitigation measures	CC	Unlikely	Moderate	Moderate	NEW	assumes implementation of responses in AMP				
WT16	Minto North Source Terms	Minto North pit walls have source water quality worse than predicted, resulting in increased loadings to McGinty Creek	significant impact to downstream aquatic resources	EI	Very Unlikely	Moderate	Low	NEW	no significant valued ecosystem components documented in McGinty Creek				
WT17	Minto North Source Terms	Minto North pit walls have source water quality worse than predicted, resulting in increased loadings to McGinty Creek	minor localized or short-term impacts to downstream aquatic resources	EI	Very Unlikely	Minor	Low	NEW	no significant valued ecosystem components documented in McGinty Creek				
WT18	Minto North Source Terms	Minto North pit walls have source water quality worse than predicted, resulting in increased loadings to McGinty Creek	resulting in implementation of mitigation measures	CC	Likely	Minor	Moderate	NEW	assumes implementation of responses in AMP				

TABLE B-6: Water Treatment Risk Register

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Water Treatment (WT)											Mitigated		
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING		CLASSIFICATION	changed?	COMMENTS	Additional Potential Mitigations	RISK RATING		CLASSIFICATION
					L	C					L	C	
WT19	Water Treatment	Blockage of high flow bypass prior to a high flow event leads to routing of all high flows through CWTS, compromising CWTS cell structure, leading to short circuiting and/or compromising of CWTS vegetation and subsequent functionality at routine flows	significant impact to downstream aquatic resources	EI	Unlikely	Moderate	Moderate	NEW	Extensive damage and performance impairment is possible, but unlikely to result in significant impact to downstream resources				
WT20	Water Treatment	Blockage of high flow bypass prior to a high flow event leads to routing of all high flows through CWTS, flushing of sediments downstream, and release of sediment-bound metals to the aquatic environment	significant impact to downstream aquatic resources	EI	Very Unlikely	Moderate	Low	NEW	Likelihood ranking is based on low likelihood of damage (above) and low potential for sediment mobilization, as the location of sediment-bound metals is under protective vegetation.				
WT21	Water Treatment	Blockage of high flow bypass prior to a high flow event leads to routing of all high flows through CWTS, compromising CWTS cell structure, leading to short circuiting and/or compromising of CWTS vegetation and subsequent functionality at routine flows	requiring maintenance and replanting beyond regular planned maintenance	CC	Possible	Moderate	Moderately High	NEW	likelihood of extensive damage is possible				
WT22	Water Treatment	Sedimentation/erosion in cells leads to channelization and non-uniform flow field, reducing CWTS treatment efficacy	significant impact to downstream aquatic resources	EI	Unlikely	Moderate	Moderate	NEW					
WT23	Water Treatment	Sedimentation/erosion in cells leads to channelization and non-uniform flow field, reducing CWTS treatment efficacy	intermittent exceedances of water quality objectives but not effects thresholds	EI	Possible	Very Low	Low	NEW	Routine monitoring and maintenance would reduce likelihood of this happening to a degree that would cause water quality objective exceedences				
WT24	Water Treatment	Willows or alders grow into wetland area, leading to channeling caused by roots and reduced treatment retention time	significant impact to downstream aquatic resources	EI	Very Unlikely	Moderate	Low	NEW					
WT25	Water Treatment	Willows or alders grow into wetland area, leading to channeling caused by roots and reduced treatment retention time	requiring repair beyond regular planned maintenance	CC	Very Unlikely	Minor	Low	NEW	Routine monitoring and maintenance would reduce likelihood of this happening to a degree that would cause water quality objective exceedences				
WT26	Water Treatment	Willows or alders grow into wetland area, leading to increased vegetation biodiversity and attraction of wildlife and disturbance of treatment system	intermittent exceedances of water quality objectives but not effects thresholds	EI	Very Unlikely	Minor	Low	NEW					
WT27	Water Treatment	Willows or alders grow into wetland area, leading to increased vegetation biodiversity and attraction of wildlife and disturbance of treatment system	requiring repair beyond regular planned maintenance	CC	Very Unlikely	Minor	Low	NEW	Routine monitoring and maintenance would reduce likelihood of this happening to a degree that would cause water quality objective exceedences				
WT28	Water Treatment	Aphid infestation damages CWTS vegetation, decreasing carbon yield and compromising subsequent years' treatment performance	intermittent exceedances of water quality objectives but not effects thresholds	EI	Unlikely	Minor	Low	NEW	Routine monitoring and maintenance would reduce likelihood of this happening to a degree that would cause water quality objective exceedences				
WT29	Water Treatment	Aphid infestation damages CWTS vegetation, decreasing carbon yield and compromising subsequent years' treatment performance	requiring pest control/replanting beyond regular planned maintenance	CC	Possible	Minor	Moderate	NEW					
WT30	Water Treatment	CWTS vegetation growth is insufficient to supply required carbon to feed treatment process	intermittent exceedances of water quality objectives but not effects thresholds	EI	Unlikely	Minor	Low	NEW					
WT31	Water Treatment	CWTS vegetation growth is insufficient to supply required carbon to feed treatment process	requiring amendment beyond regular planned maintenance	CC	Unlikely	Minor	Low	NEW	Routine monitoring and maintenance would reduce likelihood of this happening to a degree that would cause need for amendment addition				
WT32	Water Treatment	Inflow to CWTS from head pond is blocked, leading to all flow entering high flow bypass	intermittent exceedances of water quality objectives but not effects thresholds	EI	Likely	Minor	Moderate	NEW					
WT33	Water Treatment	Inflow to CWTS from head pond is blocked, leading to all flow entering high flow bypass and drying out of CWTS, compromising system functionality while vegetation re-establishes	significant impact to downstream aquatic resources	EI	Very Unlikely	Moderate	Low	NEW					
WT34	Water Treatment	lack of replacement for CWTS intallation in plan/costing at end of CWTS design life	significant impact to downstream aquatic resources	EI	Unlikely	Moderate	Moderate	NEW	RCP does not include CWTS replacement, by design. Assumes site loadings have decreased to levels not requiring polishing.				

TABLE B-6: Water Treatment Risk Register

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Water Treatment (WT)											Mitigated		
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING L	RISK RATING C	CLASSIFICATION	changed?	COMMENTS	Additional Potential Mitigations	RISK RATING L	RISK RATING C	CLASSIFICATION
WT35	Water Treatment	more than expected sedimentation in head pond and CWTS from upstream material sluffing into channels	requiring repair beyond regular planned maintenance	CC	Unlikely	Minor	Low	NEW	assumes an additional maintenance event is required				
WT36	Area 2 Pit	overturn of seasonal thermally stratified pit water, resulting in higher than expected pit discharge concentrations for short time periods	intermittent exceedances of water quality objectives but not effects thresholds	EI	Unlikely	Minor	Low	Y	Unlikely because of limited source loadings to pit				
WT37	Area 2 Pit	Discharge concentrations higher than expected when pit first discharges	short/medium term exceedances of water quality objectives but not effects thresholds	EI	Very Unlikely	Minor	Low	y	Pit water quality assumed to be carefully monitored during the transition stage; (pit takes ~ 3years to fill); Assumes treatment occurs if required.				
WT38	Area 2 Pit	Discharge concentrations higher than expected when pit first discharges	Requires treatment to meet acceptable discharge quality by time of first discharge	CC	Likely	Moderate	Moderately High	y	Pit water quality assumed to be carefully monitored during the transition stage; (pit takes ~ 3years to fill). Increased likelihood from 2014.				
WT39	Minto North Pit	Pit water quality degraded unacceptably	Unacceptable water quality conditions for water fowl / wildlife	EI	Very Unlikely	Moderate	Low	NEW	Scenario was evaluated				
WT40	Main Pit	overturn of seasonal thermally stratified pit water, resulting in higher than expected pit discharge concentrations for short time periods	intermittent exceedances of water quality objectives but not effects thresholds	EI	Unlikely	Minor	Low	NEW	shallower final depth in closure than A2 Pit, so less likely to stratify, however loading sources are higher in Main Pit, therefore rated same likelihood as A2 Pit.				
WT41	Main Pit	Discharge concentrations higher than expected when pit first discharges	short/medium term exceedances of water quality objectives but not effects thresholds	EI	Very Unlikely	Minor	Low	NEW	Pit water quality assumed to be carefully monitored during the transition stage; Assumes treatment occurs if required.				
WT42	Main Pit	Discharge water quality objectives are not met when pit first discharges	Requires treatment to meet discharge objectives by time of first discharge	CC	Likely	Moderate	Moderately High	NEW	Pit water quality assumed to be carefully monitored during the transition stage; Assumes treatment occurs if required.				
WT43	Main Pit	Wave action and suspension of tailings mobilizes tailings material out of MPTMF	intermittent exceedances of water quality objectives but not effects thresholds	EI	Possible	Minor	Moderate	NEW		will be mitigated by ensuring that tailings cover in MPTMF will extend to 1m depth below final	Very Unlikely	Minor	Low
WT44	Primary Channels	SWD toe seepage collection systems inadequate	Unacceptable WQ downstream	EI	Very Unlikely	Moderate	Low	Y	Reclamation research (seepage monitoring) has not identified substantial loading that could be mitigated by a seepage collection system				

APPENDIX C.
2017 FMEA Risk Matrices

Risk Matrix - Overall Summary (2018-01)

Risk Classification

Likelihood		1 Very Low	2 Minor	3 Moderate	4 Major	5 Critical
Almost Certain	5					
Likely	4		WT18, WT32, W10	WT38, WT42		
Possible	3	P16, P17, P27, WT23, W11	T2, T3, D5, D12, D14, D18, D19, D29, D30, D30, WT11, WT29, W22, W23, W24	WT21, A4	A5, A6	
Unlikely	2	P1, P19, P21, P22, D10, D24, W29, W30	P8, P9, P11, P12, T1, T7, T11, T12, T13, D4, D6, D11, D13, D20, D31, D31, WT2, WT5, WT8, WT14, WT28, WT30, WT31, WT35, WT36, WT40, W5, W6, W14, W27, W33, W36, W37, A3	WT1, WT4, WT6, WT7, WT9, WT10, WT13, WT15, WT19, WT22, WT34	A1	WT3, WT12
Very Unlikely	1	P14, D27, W3, W4, W15, W17	P23, T4, T8, T9, D23, D26, WT17, WT25, WT26, WT27, WT37, WT41, WT43, W1, W2, W7, W8, W16, W18, W19, W20, W32	P5, P6, P10, P15, P18, P20, P24, P25, P26, T10, D1, D2, D3, D7, D8, D9, D15, D16, D17, D21, D22, D25, WT16, WT20, WT24, WT33, WT39, WT44, W9, W13, W21, W28, W31	T5, T6, D28, W12, A8	P7, P13, A7

Consequence

Risk Matrix - Open Pits (P) (2018-01)

Risk Classification

Likelihood							
Almost Certain	5					
Likely	4					
Possible	3	P16, P17, P27				
Unlikely	2	P1, P19, P21, P22	P8, P9, P11, P12			
Very Unlikely	1	P14	P23	P5, P6, P10, P15, P18, P20, P24, P25, P26		P7, P13
		1	2	3	4	5
		Very Low	Minor	Moderate	Major	Critical
		Consequence				

Risk Matrix - Dry Stack Tailings Storage Facility (T) (2018-01)

Risk Classification

Likelihood		1 Very Low	2 Minor	3 Moderate	4 Major	5 Critical
Almost Certain	5					
Likely	4					
Possible	3		T2, T3			
Unlikely	2		T1, T7, T11, T12, T13			
Very Unlikely	1		T4, T8, T9	T10	T5, T6	

Consequence

Risk Matrix - Waste Rock Dumps (D) (2018-01)

Risk Classification

Likelihood			1 Very Low	2 Minor	3 Moderate	4 Major	5 Critical
Likelihood	Almost Certain	5					
Likelihood	Likely	4					
Likelihood	Possible	3		D5, D12, D14, D18, D19, D29, D30, D30			
Likelihood	Unlikely	2	D10, D24	D4, D6, D11, D13, D20, D31, D31			
Likelihood	Very Unlikely	1	D27	D23, D26	D1, D2, D3, D7, D8, D9, D15, D16, D17, D21, D22, D25	D28	

Consequence

Risk Matrix - Water Treatment (WT) (2018-01)

Risk Classification

Likelihood		1 Very Low	2 Minor	3 Moderate	4 Major	5 Critical
Almost Certain	5					
Likely	4		WT18, WT32	WT38, WT42		
Possible	3	WT23	WT11, WT29	WT21		
Unlikely	2		WT2, WT5, WT8, WT14, WT28, WT30, WT31, WT35, WT36, WT40	WT1, WT4, WT6, WT7, WT9, WT10, WT13, WT15, WT19, WT22, WT34		WT3, WT12
Very Unlikely	1		WT17, WT25, WT26, WT27, WT37, WT41, WT43	WT16, WT20, WT24, WT33, WT39, WT44		

Consequence

Risk Matrix - Water Conveyance (W) (2018-01)

Risk Classification

Likelihood			1 Very Low	2 Minor	3 Moderate	4 Major	5 Critical
Likelihood	Almost Certain	5					
	Likely	4		W10			
	Possible	3	W11	W22, W23, W24			
	Unlikely	2	W29, W30	W5, W6, W14, W27, W33, W36, W37			
	Very Unlikely	1	W3, W4, W15, W17	W1, W2, W7, W8, W16, W18, W19, W20, W32	W9, W13, W21, W28, W31	W12	

Consequence

Risk Matrix - Administrative (A) (2018-01)

Risk Classification

Likelihood							
Likelihood	Almost Certain	5					
	Likely	4					
	Possible	3			A4	A5, A6	
	Unlikely	2		A3		A1	
	Very Unlikely	1				A8	A7
			1	2	3	4	5
			Very Low	Minor	Moderate	Major	Critical
			Consequence				

APPENDIX D.

Summary of Risks Not Re-Evaluated in 2017 FMEA

TABLE D-1: 2014 FMEA Entries not Re-evaluated

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Not Re-evaluated (NR)									
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING L	RISK RATING C	CLASSIFICATION	2014 COMMENTS	Rationale for Not Re-evaluating Risk
R1	Area 2 Pit	Precipitation higher than design asssumption (1:200 yr 24 hr)	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	TU	Very Unlikely	Major	Moderate		Consequence Category not utilized in 2017 Workshop
R2	Area 2 Pit	Precipitation higher than design asssumption (1:200 yr 24 hr)	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	RL	Very Unlikely	Major	Moderate		Consequence Category not utilized in 2017 Workshop
R3	Area 2 Pit	Precipitation higher than design asssumption (1:200 yr 24 hr)	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	CMR	Very Unlikely	Critical	Moderately High		Consequence Category not utilized in 2017 Workshop
R4	Area 2 Pit	Pit water quality degraded unacceptably (dissolved constituents)	Unacceptable water quality conditions for water fowl / wildlife	TU	Unlikely	Moderate	Moderate	Scenario needs to be evaluated; water quality that could affect water fowl needs to be researched and shared.	Consequence Category not utilized in 2017 Workshop
R5	Area 2 Pit	Pit water quality degraded unacceptably (dissolved constituents)	Problematic exceedances of site water quality discharge standards	RL	Possible	Moderate	Moderately High		Consequence Category not utilized in 2017 Workshop
R6	Minto North Pit	Positive water balance for pit leads to development of pit lake	results in negative perception leading to negative impacts on traditional land use	TU	Possible	Minor	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.	Consequence Category not utilized in 2017 Workshop
R7	Minto North Pit	Pit water quality degraded unacceptably	Unacceptable water quality conditions for water fowl / wildlife and results in some mitigatable impact to tradtional land use	TU	Very Unlikely	Moderate	Low	Assumes AMP does not exist or is not implemented	Consequence Category not utilized in 2017 Workshop
R8	DSTSF/MVFE	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	Impounding of water and subsequent rapid breach and sediment loading downstream	EI	Possible	Minor	Moderate	Consider including in post-closure monitoring	Expanded upon in Water Convenyance Category
R9	Main Waste Dump	Precipitation higher than expected	Failure of water conveyance structures because structures are underdesigned					Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA	Addressed in Water Conveyance Category
R10	Main Waste Dump	Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration	Ongoing maintenance costs					Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA	Addressed in Waste Rock Dump Category
R11	Southwest Waste Dump	SWD toe seepage collection systems inadequate	Unacceptable WQ downstream					Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA	Addressed in Water Treatment Category
R12	Southwest Waste Dump	Precipitation higher than expected	Failure of water conveyance structures because structures are underdesigned					Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA	Expanded upon in Water Convenyance Category

TABLE D-1: 2014 FMEA Entries not Re-evaluated

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Not Re-evaluated (NR)									
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING		CLASSIFICATION	2014 COMMENTS	Rationale for Not Re-evaluating Risk
					L	C			
R13	Southwest Waste Dump	Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration	Ongoing maintenance costs					Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA	Addressed in Waste Rock Dump Category
R14	Southwest Waste Dump	Existing pond north of MGW/ south of IROD remains in post-closure	Causes community concern	CMR	Almost Certain	Very Low	Moderate	Will be revisited in detailed design and could be mitigated through education and information sharing	Consequence Category not utilized in 2017 Workshop
R15	Ridgetop Waste Dump	Precipitation higher than expected	Failure of water conveyance structures because structures are underdesigned					Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA	Addressed in Water Conveyance Category
R16	Ridgetop Waste Dump	Ridgetop Waste Dump name	Creates perception that there will be major viewshed impacts	CMR	Possible	Minor	Moderate	Could be mitigated through education and information sharing	Consequence Category not utilized in 2017 Workshop
R17	Reclamation OVB, Ridgetop South & Area 118 Backfill Dumps	Precipitation higher than expected	Failure of water conveyance structures because structures are underdesigned					Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA	Addressed in Waste Rock Dump Category
R18	Reclamation OVB, Ridgetop South & Area 118 Backfill Dumps	Undiverted runoff upstream of waste mgmt facilities leads to runon water, extra infiltration	Ongoing maintenance costs					Scenario wording copied from 2013 risk register-topic covered in #12 in 2014 FMEA	Addressed in Waste Rock Dump Category
R19	Reclamation OVB, Ridgetop South & Area 118 Backfill Dumps	Ponding of water on surface of overburden dumps leads to excessive infiltration, increases flow subsurface and contaminant loading from overburden	Unacceptable downstream water quality	EI	Very Unlikely	Moderate	Low	Designs of A118 and RS BD are mounded to shed water.	Addressed in Waste Rock Dump Category
R20	Reclamation OVB, Ridgetop South & Area 118 Backfill Dumps	Erosion on steeper portions of dumps	Sedimentation in conveyance channels and need for maintenance					Scenario topic covered in #12 in 2014 FMEA	Addressed in Waste Rock Dump Category
R21	Reclamation OVB, Ridgetop South & Area 118 Backfill Dumps	Storage of overburden in pits	Creates perception that valuable reclamation materials are being wasted	CMR	Almost Certain	Minor	Moderately High	Could be mitigated through education and information sharing	Consequence Category not utilized in 2017 Workshop
R22	Site wide	Source water quality (source term) worse than predicted	Problematic exceedances of downstream water quality objectives	CMR	Unlikely	Critical	Moderately High		Consequence Category not utilized in 2017 Workshop
R23	Main Dam	Thaw degradation leading to differential settlment of spillway, distruption of the armour layer, and scour of the spillway	Need for repairs	CC	Possible	Moderate	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.	Main Dam no longer part of Mine Plan/RCP

TABLE D-1: 2014 FMEA Entries not Re-evaluated

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Not Re-evaluated (NR)									
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING L	RISK RATING C	CLASSIFICATION	2014 COMMENTS	Rationale for Not Re-evaluating Risk
R24	Main Dam	Thaw degradation leads to retrogressive failure at outlet of main pit spillway	Need for repairs	CC	Possible	Moderate	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.	Main Dam no longer part of Mine Plan/RCP
R25	Main Pit	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	Unacceptable water quality conditions downstream of site	EI	Very Unlikely	Very Low	Low		Configuration of Main Pit at closure has changed - addressed in Pit Category
R26	Primary Channels	Increased infiltration through unlined Ditch 200 and Ditch 300	Unacceptable water quality conditions downstream of site	EI	Very Unlikely	Moderate	Low		Ditch configuration/design has changed - addressed in Water Conveyance Category
R27	Site wide (Admin)	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.)	Negative traditional use	TU	Likely	Critical	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	Consequence Category not utilized in 2017 Workshop
R28	Site wide (Admin)	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.)	Regulatory/legal action	RL	Possible	Critical	High	-Assumes company remains the responsible company.	Consequence Category not utilized in 2017 Workshop
R29	Site wide (Admin)	General failure to conduct preventative mainenance and corrective actions leading to system failures (passive treatment, covers, etc.)	Community/media/reputation impacts	CMR	Likely	Critical	Very High	media and reputation aspects of the concequence severity description were disregarded in rating.	Consequence Category not utilized in 2017 Workshop
R30	Site wide (Admin)	Revegetation does not meet closure objectives relating to end land use	Negative traditional use	TU	Possible	Moderate	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	Consequence Category not utilized in 2017 Workshop
R31	Site Wide	Failure to adequately meet reporting requirements	Noncompliance	RL	Possible	Minor	Moderate		Consequence Category not utilized in 2017 Workshop

TABLE D-1: 2014 FMEA Entries not Re-evaluated

Minto Explorations Ltd.
Minto Mine
FAILURES MODES AND EFFECTS ASSESSMENT

Not Re-evaluated (NR)									
RISK NO.	AREA	RISK DESCRIPTION	CONSEQUENCE	CON. TYPE	RISK RATING		CLASSIFICATION	2014 COMMENTS	Rationale for Not Re-evaluating Risk
					L	C			
R32	Area 2 Pit	Pit water quality degraded unacceptably (dissolved constituents)	Problematic exceedances of downstream water quality objectives	EI	Possible	Moderate	Moderately High	Assumes AMP in place, and discussed it being a short term impact - particularly with current AMP which addresses site water and pit water quality, but retained it as a moderate severity.	Expanded upon in Pit Category
R33	Minto North Pit	Pit water quality degraded unacceptably	Problematic exceedances of downstream water quality objectives	EI	Possible	Moderate	Moderately High	Assumes AMP does not exist or is not implemented	Expanded upon in Pit Category

Appendix E1
Scoping Level Cover Assessment for Minto Closure Covers

Scoping Level Cover Assessment for Minto Closure Covers

Prepared for

Minto Explorations Ltd.

Prepared by

SRK Consulting (Canada) Inc.
1CM002.007
August 2013

Scoping Level Cover Assessment for Minto Closure Covers

August 2013

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File Name: Minto_Final_Scoping Level Cover Assessment_1CM002 007_20130822_EMR_DBM_CCS

srk consulting

Executive Summary

Minto Explorations Ltd. (Minto) is considering the use of covers as one of the remedial strategies for mine waste at their Minto Mine site in Yukon Territory, Canada. Mine waste at Minto site includes both waste rock and tailings (dry stack and in-pit tailings). At the end of Phase IV (the current phase of mining), there will be six distinct waste rock and overburden piles on site, and these will be expanded as future mine development takes place.

Geochemical characterization of the mine waste has confirmed that acid generation potential is low; however, neutral metal leaching will be a long-term concern. This scoping level cover assessment provides a comprehensive evaluation of appropriate cover design concepts that should be considered for the Minto site, taking into account site specific conditions and overall site wide closure objectives.

Mine waste covers are one remedial technology that can be used to manage drainage. Successful closure covers over mine waste facilities depend on many factors; however, two factors dominate decisions on what may be appropriate at any specific site, i.e., climatic conditions and locally available material (i.e., soils).

The evaluation demonstrates that the hydrologic and climatic regime at the Minto site is best suited to the use of water covers or infiltration reducing covers (i.e., barrier covers). In contrast, store-and-release and thermal covers are not likely to be successful. The available overburden soils at Minto are however not well suited for construction of low or very low infiltration barrier covers.

These soils are best used as isolation and vegetation supporting covers, and are expected to result in overall infiltration typically between 10 and 20% of mean annual precipitation.
Periodic higher breakthrough events will occur. Soil amendments or use of synthetic products are therefore required to construct low to very low infiltration covers at the site. Conceptual designs of each of these different cover variants are proposed.

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1 Introduction

1.1 Background

Minto Explorations Ltd. (Minto) is considering the use of covers as a remedial strategy at their Minto Mine site in Yukon Territory, Canada. The general concepts of this plan are documented in Minto's current Decommissioning and Reclamation Plan (D&RP) (Minto 2011). A rigorous assessment of the proposed cover concepts taking into account site specific conditions has not been carried out and therefore the cover design concepts are not optimized. This work is intended to provide a rationale for how covers can best be utilized at Minto.

Mine waste at Minto includes both waste rock and tailings. At the end of Phase IV (the current phase of mining) there will be six distinct waste rock and overburden piles on site as illustrated on Figure 1, and these will be expanded as future mine development takes place.

Historic tailings deposition consisted of dry-stacked compacted filtered tailings. This deposition strategy was discontinued in October 2012, in favour of conventional low solids content (50 to 60% by mass) slurry tailings deposited sub-aqueously into Main Pit. Future tailings deposition will continue as hydraulically deposited tailings in Main and Area 2 Pits.

Geochemical characterization carried out on both waste rock and tailings confirms that, for the most part, the mine waste is not highly reactive, and has very low potential to generate acid; however, there is potential for neutral metal leaching (SRK 2013a). Mitigation strategies are therefore required to manage this leachate, including water treatment, waste relocation and waste encapsulation (i.e., closure covers).

1.2 Scope of Work

While it is understood that covers are one of many possible mitigation strategies that can be used to achieve site wide closure objectives, the scope of this study was to specifically determine what cover concepts are most likely to be successful at Minto, and how best to implement them. This was done by carefully evaluating site specific conditions that affect cover design, construction and ultimately long-term performance, including but not limited to design life, climate, material availability, waste characterization, seismicity, slope stability, erosion resistance, etc.

Once the cover concepts that are most likely to be successful at Minto were identified, appropriate cover functions were defined to specifically ensure overall site wide closure objectives would be met. Finally conceptual cover designs are presented that demonstrate actual implementation plans for all of the concepts.

1.3 Report Layout

Specific design elements that need to be considered in cover design are described in Section 2. Section 3 of this report describes the different cover types and whether they should be given consideration at Minto. Section 4 provides a generalized overview of the currently stated site wide closure objectives, complete with preliminary suggestions for cover functionality. Finally, different conceptual cover designs suitable for application at Minto, complete with expected performance criteria, are presented.

2 General Cover Design Elements

2.1 Cover Design Life

SRK does not believe that engineered soil covers can be expected to continue to perform in accordance with their original design intent for an infinite lifetime after construction (i.e., in perpetuity), especially if there is no monitoring and maintenance plan in effect. Therefore, it is appropriate to design soil covers and associated monitoring and maintenance plans with a finite lifespan in mind. The length of that time period should dictate to what standard the cover must be designed and constructed, and also what level of monitoring and maintenance would be required.

There are no specific guidelines or standards in Canada that specify a lifespan for covers, leaving the design decision to the discretion of the mine operator. Internationally, there are also no fixed criteria for cover lifespan; however, some mining companies explicitly adopt life spans of 100, 200 or even 500 year periods during which the cover is expected to perform in accordance with the original design intent (Rykaart *et al*. 2006).

The design life of a cover is complicated by the fact that some cover failure modes require inherently different approaches. For example, if Minto was to adopt a design life for the conceptual cover designs presented in this report of say 200 years, then it would be assumed that these covers would continue to perform the functions listed in Section 4 for this lifespan. However, portions of the cover design may have different design criteria, for example surface water conveyance channels may be designed to withstand 1:100 year storm events with an understanding that the necessary maintenance and repair would be carried out for the 200 year design life of the cover.

It would be premature for SRK to recommend a design life for the Minto covers in isolation of the overall closure design, as well as input from stakeholders. A risk assessment approach can be used during detailed design to evaluate the consequences of the different cover failure modes and what the optimal cover design life should be.

2.2 Site Climate

Site specific climate is one of the primary drivers that define what the most appropriate and sustainable cover may be for any given project area. The three dominating climatic parameters include the climatic water balance, air temperature, and radiation energy.

Site specific climate data is available with records from two onsite weather stations. Both stations have data from 2005 to 2011; however, the datasets are incomplete and generally too short to be useable or representative for a scoping level cover assessment. Regional climate data is available from the Pelly Ranch station, managed by Environment Canada. This station is located about 25 km north of Minto and has data dating back to 1955.

Based on the Pelly Ranch data, the mean annual total precipitation (MAP) for Minto is estimated to be about 335 mm. Roughly 50% of this precipitation falls as rain, with the remainder being the snow water equivalent of the annual snowpack. The maximum annual precipitation on record is 466 mm.

Monthly lake evaporation (aka potential evaporation) has been recorded at the Pelly Ranch station from 1965 to 2005 and the mean annual lake evaporation is 452 mm. Site specific data suggest that the mean annual evaporation is closer to 430 mm (Clearwater 2008) and 438 mm (Clearwater 2010). EBA (2010) applied an elevation correction to the Pelly Ranch data (1971-1990) to reduce the mean annual evaporation to 400 mm. SRK calculated the mean annual evaporation from first principles using the FAO method (FAO 1998) which computes to 410 mm evaporation per year. For the purpose of this study, the mean annual evaporation was selected based on the elevation correction presented by EBA (2010) to the Pelly Ranch evaporation data to yield a mean annual evaporation of 400 mm. The mean monthly climatic water balance based on this data is presented in Figure 2 and it demonstrates that between March and September, the climatic water balance is net negative, i.e., evaporation exceeds precipitation. This highly seasonal water balance deficit on a near neutral annual water balance makes it challenging to determine the most suitable cover type and a more in depth analysis of the climate is required.

Using the elevation corrected annual lake evaporation and precipitation data from Pelly Ranch from 1965 to 1995, the Thornthwaite and Mather (1955) Moisture Index was calculated to provide an indication of the site climate classification taking into consideration both water and temperature influences. This is presented in Figure 3 and confirms, generally, the site can be classified as Dry Subhumid; however, over the years the site spans both the Moist Subhumid and Semi-Arid climate zones.

The climatic water balance and climate classification are good indicators for what the most appropriate cover type would be at any given site and this is illustrated for Minto on Figure 4. This graph has been adapted from the Holdridge *et al*. (1971) life zone classification, as presented in the Global Acid Rock Drainage (GARD) Guide (INAP 2012). The data confirms that the site is best suited towards either water covers or infiltration controlling (i.e., barrier type) covers. Store-and-release and thermal covers on the other hand are not recommended for the site based on climatic conditions.

The mean monthly ambient air temperature for the site is also plotted on Figure 2. The annual average ambient air temperature is -4^{o}C. This leads to seasonal ground freezing, and site specific measurements suggest that the annual depth of frost penetration is less than 4 m. The site is also located in the discontinuous permafrost region of Canada and where permafrost is present, it is generally relative warm at about -1^{o}C.

Empirical methods were used to determine the annual depth of frost penetration at Minto, which amounts to between 2 and 3.5 m depending on soil porosity, water content and bulk density. Therefore, any low permeability barrier cover that could be damaged through freeze-thaw action would have to be constructed with a protection cover of at least 3 m.

Freezing temperatures also lead to a unique moisture distribution profile which is important when considering possible covers. During spring, significant surface runoff is present in the form of snowmelt; however, during this time the ground is still frozen and therefore water is less likely to infiltrate. When considering the climatic water balance illustrated in Figure 2, it appears that during spring (freshet) and early summer, when the most runoff is expected, the highest evaporation potential exists.

Figure 5 provides an overall climate wheel for the Minto site which summarizes key dates and timelines which will affect cover performance from both a hydrologic and physical perspective.

2.3 Potential Cover Materials

Locally available candidate cover soils consist of the overburden soils which can generally be classified as silty sands. Numerous geotechnical characterization programs have been carried out over the years including a dedicated cover soil characterization program in 2012 (SRK 2013b).

Three primary candidate cover soil sources have been identified as illustrated in Figure 1; (1) overburden stockpiled on the Main Waste Dump (MWD); (2) the Reclamation Overburden Dump (ROD); and (3) the Ice-Rich Reclamation Overburden Dump (IROD). Additional material is currently being developed from Area 2, Stage 2 Pit development and is being stockpiled on the Dry Stack Tailings Storage Facility and the Reclamation Overburden Dump. In total, it is estimated that there is about 2.8 Mt of these soils available for use as cover material.

Indicator property characterization testing has been completed on these soils (i.e., particle size distribution and Atterberg Limits) and the summarised results are presented in Figures 6 and 7. Their results demonstrate that there is minimal variability in the available material when considering its use a candidate cover source. Based on the overall grain size distribution envelope for all of the candidate cover soils (Figure 6), nine curves were initially selected to represent the possible range in cover performance (Figure 8).

Hydraulic testing (i.e., porosity, saturated hydraulic conductivity and Soil Water Characteristic Curves (SWCC)) was carried out on select samples and the results are summarized in Table 1 and Figure 9. Prior to the completion of the SWCC testing, six of the nine samples in Figure 8 were chosen and SWCCs were estimated using empirical methods. These resultant curves are illustrated in Figure 10. Comparisons of these estimated curves with the measured curves are presented in Figures 11 through 13. The final six calibrated SWCCs that were used in the cover analysis presented in this report are presented in Figure 14.

The MWD overburden material is sandy, lean clay (CL, in accordance with the Unified Soil Classification System). The porosity is estimated at about 36% and saturated hydraulic conductivity is about 1.38 x 10^{-7} m/sec. The air entry value is estimated to be between 23.1 and 71.9 kPa.

Materials from the ROD and IROD range from silty sands to clayey sands (SM-SC). Porosity is estimated at 29% to 31%, and saturated hydraulic conductivity ranges between 7.72 x 10^{-8} and 9.24 x 10^{-8} m/sec. The air entry value is estimated to range between 1.5 and 12.1 kPa.

Table 1: Hydraulic properties of overburden material from MWD, ROD, and IROD

Material Type	Porosity	Saturated Hydraulic Conducticity (m/s)	Field Capacity (VWC)	Wilting Point (VWC)	Storage Capacity (VWC)	Air Entry Value (kPa)
MWD1	36.0%	1.38 x 10^{-7}	0.339	0.223	0.116	71.9
MWD2	36.0%	1.38 x 10^{-7}	0.304	0.192	0.112	23.1
ROD2	31.0%	9.16 x 10^{-8}	0.260	0.160	0.100	12.1
ROD3	29.0%	7.72 x 10^{-8}	0.176	0.112	0.065	1.5
IROD1	31.0%	9.24 x 10^{-8}	0.243	0.127	0.116	4.8
IROD2	30.5%	8.79 x 10^{-8}	0.202	0.122	0.080	1.7

Three properties dominate the suitability of material as it relates to its use as a candidate cover material. First, for barrier covers intended to reduce infiltration, the saturated hydraulic conductivity is the most important. As a general rule of thumb, a soil should have a saturated hydraulic conductivity of at least 1 x 10^{-8} m/s (315 mm/year) to be considered an infiltration barrier.

Secondly, the property that dominates the suitability of a store-and-release type cover is how well graded it is, which translates into its moisture holding capacity (i.e., difference between its air entry value and residual suction). The moisture holding capacity is often simplified in terms of the Storage Capacity as listed in Table 1. This is calculated as the difference between the soil's Field Capacity and Wilting Point. Field Capacity correlates closely to the air entry value but is generally considered to be the volumetric moisture content of a soil at a soil suction of 33 kPa. Likewise, the Wilting Point correlates closely with the residual suction, but is generally considered to occur at a suction of about 1,500 kPa. The Field Capacity is the point where a soil starts to de-saturate, and the Wilting Point is the point where plants are no longer able to extract moisture from the soil pore space. Generally the greater the storage capacity of a soil, the greater the potential for being an efficient store-and-release cover, provided the climate is suitable.

Lastly, a soil cover must resist surface erosion and therefore silty soils, which are highly prone to erosion, are normally considered less desirable.

It can therefore be concluded that the available soils at Minto are not ideal store-and-release materials (although certainly workable) and are definitely not suitable for construction of low infiltration (barrier) covers. Construction of such covers will require intervention such as adding bentonite.

2.4 Waste Settlement

Mine waste settlement, specifically differential settlement can affect cover integrity. The waste rock dumps and dry-stack tailings at Minto are not expected to undergo significant settlement; however, the tailings in Main Pit will undergo settlement as a result of self-weight consolidation, as well as the surcharge from cover placement.

Consolidation testing has not been done on the Main Pit tailings; however, based on general experience with similar tailings it is conceivable that tailings consolidation, and associated cover settlement could be around 30 cm on the exposed beaches, and up to 1 m on the slimes regions near the central pond area (not accounting for entrained ice). Such settlement could affect cover integrity, and therefore the cover design should either compensate for potential settlement, or construction should only be done once settlement is complete.

Complete tailings settlement will require tailings dewatering, and even then it could take years or even decades. Therefore, it is recommended that the Main Pit tailings impoundment cover design be such that up to 1 m of settlement would still result in the cover performing as designed.

2.5 Seismicity

According to the 2010 National Building Code of Canada seismic hazard calculator, the corresponding peak ground acceleration (PGA) for the Minto site is 0.057 g for a 2% probability of exceeding in 50 years (1 in 2,500). This means that this site is not particularly seismically active.

Assuming the cover is constructed from a non-liquefiable material, seismic action will affect cover integrity in two ways:

First, a cover placed on steep side slopes not subject to liquefaction, would be subject to classic failure mechanisms such as increased pore water pressures induced by ground shaking. At the Minto site this failure mechanism would only apply to covers constructed on the waste rock pile and dry-stack tailings impoundment.

Second, a cover constructed on potentially liquefiable material such as the Main Pit tailings could cause surface manifestations of liquefaction in the cover in the form of cracks and boils.

The occurrence of such surface manifestations, assuming liquefiable tailings at depth, is a function of the thickness of the non-liquefiable cap (cover plus the unsaturated tailings layer). For a cap thickness greater than 3 m, case histories (Ishihara 1985, as reported by Ritchie (1999)) suggest that there will not be a surface manifestation for ground surface accelerations up to 0.2 g. Since this is an order of magnitude greater than the design earthquake this is not considered to be a concern.

2.6 Trafficability/Constructability

The construction of any cover over saturated tailings is challenging, due to the fact that construction equipment cannot travel over the surface that needs to be covered. This means that the cover has to be constructed in one of five possible ways:

1. Construction of the tailings cover is delayed until the tailings have had enough time to naturally dewater such that equipment can safely travel on it. The problem with this approach is that this process can take very long, i.e. many years, if ever.
2. The tailings are actively dewatered through installation of wick drains or other similar dewatering devices. This can be cost prohibitive, and still must address the issue of access onto the tailings for the installation of these dewatering devices.
3. A platform is developed from the perimeter of the saturated zone by dumping cover material and dozing it over the saturated tailings. This platform becomes the working base for the construction equipment as it advances. The problem with this method is the amount of cover material that is required is significantly greater due to the requirement for a trafficable surface, and often a tailings bow wave forms immediately ahead of the working face. This results in an uneven tailings surface which may add to the need for increased cover material.
4. Cover construction can sometimes be done with specially modified low ground pressure equipment. This still requires a de-saturated surface layer, and the equipment is highly specialized and expensive.
5. Construct the cover in winter, after the frost has penetrated to a depth sufficient to support construction equipment.

Cover construction at Minto over the slimes zones of the Main Pit tailings impoundment will definitely be subject to trafficability challenges. Therefore, any cover design does need to mitigate these challenges, for example by doing winter construction to take advantage of a frozen tailings surface.

For the dry-stack tailings impoundment and the waste rock piles cover constructability should not be too much of a concern, provided that where possible the side slopes be kept flatter than 33% (3H:1V). Cover placement on steeper slopes becomes less efficient. Should geosynthetics be used, slopes may have to be flattened to as low as 20% (5H:1V).

2.7 Physical Exposure of Mine Waste

Physical exposure of mine waste is a human and terrestrial health and safety concern at mine sites (including Minto). Exposure pathways include direct physical contact, as well as indirect contact via dust and overland surface runoff. In order to mitigate this, any physical separation cover over the mine waste areas would suffice. There may however be other cover design criteria that could dominate such as infiltration control, and therefore a cover for the sole purpose of separation may not be appropriate at Minto.

2.8 Oxygen Reduction

As previously documented, geochemical characterization of the tailings and waste rock suggest that rapid oxidation is not a concern. Therefore construction of oxygen limiting/reducing covers at Minto is not warranted.

2.9 Infiltration Reduction

It has already been documented that the available cover materials are not good candidate materials to construct effective barrier covers, even if well compacted. Furthermore, in most cases, the saturated hydraulic conductivity of the mine waste is less than or equal to the available cover material, further negating the possible usefulness of constructing barrier covers with these candidate cover materials. Although data is not available it is estimated that the saturated hydraulic conductivity of the dry-stack tailings is about 1×10^{-7} m/sec (3,154 mm/year), and the Main Pit tailings (beach tailings) would be similar. The slimes would be at least an order of magnitude less (i.e., 1×10^{-8} m/sec or 315 mm/year). Data for the waste rock is not available but it is likely to be about 1×10^{-4} m/sec (3,153,600 mm/year).

Site specific water balance calculations suggest that about 30% (Clearwater 2010) of precipitation gets discharged as overland runoff at the Minto site. Very little overland runoff is however observed and, in reality, the bulk of this volume is actually shallow infiltration which emerges as stream flow downstream of the Minto site at the flow gauging station. Therefore it is not unreasonable to assume, in the absence of specific infiltration analysis, that although the available soils would allow for construction of store-and-release covers, they would likely not be able to consistently perform to a standard better than reducing infiltration to about 20% of mean annual precipitation.

As a result, in all likelihood, the only viable method to reduce infiltration further would be to make use of a synthetic cover, or alternately a bentonite-amended barrier layer.

2.10 Slope Stability

For the most part, the cover designs at Minto will be on relatively flat surfaces. The waste rock piles and dry-stack tailings impoundment have been designed with final slopes of either 2.5H:1V or 3H:1V which would support efficient cover construction, provided the slopes are not too long. Should geosynthetic covers be required, these slopes may be considered too steep.

2.11 Wind Erosion

The fines content of the candidate cover material suggest that, under prolonged dry periods, wind erosion could be a concern with respect to cover integrity. Appropriate mitigation strategies could include sacrificial increase of the cover thickness to compensate for material loss over time, or providing a physical barrier against wind erosion.

Wind erosion is a complex phenomenon and is a function of the soil properties, climate and the vegetation characteristics. Wind erosion simulation models can be used to evaluate what the potential soil loss would be; however, the lack of data precludes the use of such models at this time.

A number of physical wind erosion studies provide some useful indicative data to use as a first order estimate of wind erosion rates in this conceptual design. Forward *et al*. (2004) reported that the annual soil loss through wind erosion from agricultural land in Southern Australia ranges between 0.01 and 0.06 mm/year. Basher and Webb (1997) reported wind erosion rates in bare soil in New Zealand of 0.90 mm/year. Based on this data, a sacrificial increase in soil thickness for a 200 year cover design life would be between 3 and 180 mm. However, considering the uncertainty associated with these estimates, the difficulty in transposing the data to a site specific condition, combined with the risk of exposed mine waste, mitigation against wind erosion through sacrificial increase of the cover should be considered a potential optimization strategy at this time.

An alternative method of preventing wind erosion would be to construct a physical barrier (i.e., some form of armouring such as fine gravel) on the erosion susceptible soil cover. Since there is no readily available source of such a material at Minto, this mitigation measure is likely not viable.

Cover stabilization using vegetation is commonly acknowledged and is likely the preferred method of wind erosion stabilization for the site.

2.12 Overland Surface Runoff

The high silt content of the cover soils suggest that surface erosion will be a problem. Just as with wind erosion, overland surface water erosion rates are difficult to estimate, and can be managed by adding sacrificial cover material, or providing a suitable physical barrier. The thickness of a sacrificial cover layer cannot be estimated at this time; and further optimization in this area is recommended.

Similar to wind erosion, a definite method of ensuring that erosion protection is provided in the long-term would be to clad the erosion susceptible cover with erosion resistant soil or rip-rap. Since there is no readily available material of this nature at Minto (other than waste rock), this alternative is not recommended.

Vegetation is a proven erosion stabilization technique and is therefore the preferred mitigation strategy against overland surface runoff. To further reduce the risk of developing erosion gullies, appropriate landform engineering must be carried out to promote the development erosion resistant landforms.

It is important to remember that water shed by runoff has to be safely conveyed over the cover to its receiving environment. Therefore, the cover design must account for the volume, frequency and intensity of runoff that is anticipated and the seamless integrated designs of the cover and conveyance channel contact zones are integral to the overall success of the cover.

Naturally, more runoff implies that less water is available for infiltration. This presents potential opportunities that are of relevance in selecting a suitable cover design for the Minto site. Firstly, if a significant portion of the freshet season infiltration is shed as runoff, then the amount of infiltration that has to be accounted for in a store-and-release cover becomes less, and the likelihood of reaching a workable ratio of infiltration versus potential evaporation increases (although it may still not be enough), making this type of cover more viable.

2.13 Evapo-Concentration

Chemical constituents present in the mine waste pore water, specifically salts, can be transported up (“wicked”) towards the waste surface, and continue up through the cover soil due to capillarity associated with upward fluxes caused by evaporation. This problem, also termed evapo-concentration, is common in net negative climates where the predominant flux is upward. If evapo-concentration occurs, it leads to contamination of surface water, which would constitute as non-compliance with the site closure objectives. During the wet season, there would be a constant variability of the flux within the cover, but evapo-concentration is not likely to be a major concern. However, during prolonged dry periods, the predominant flux would be upwards, especially if the underlying waste has a high moisture content. As a result evapo-concentration is not expected to be much of a concern at Minto.

This can however be mitigated by making the cover thick enough that all the meteoric action occurs within the cover with no contribution from the underlying waste, or by including a physical barrier in the cover that prevents this pore water from migrating up through the cover. The most common physical barrier is a capillary break. Since evapo-concentration is not expected to be a concern at Minto, the cover design will not take this into consideration.

2.14 Root Uptake

Allowing vegetation to establish on the final Minto closure covers is probably the most sustainable long-term solution, notwithstanding the limited growing season. A vegetative cover offers benefits in terms of reducing meteoric infiltration through increased evapotranspiration, whilst also providing erosional stability from wind and surface runoff. Disadvantages of a vegetative cover include creation of preferential flow paths through root penetration, and potential contaminant uptake from the underlying waste by the plant root systems to the surficial plant biomass, which in turn could pose a terrestrial exposure risk.

Mitigation against root uptake could include limiting plant growth outright, or constructing a chemical or physical root barrier as part of the cover. Outright prevention of vegetation can only be done through active site management, since even if coarse rock is used as a cover, dust and seed will be transported to the cover over time through wind from neighbouring undisturbed land and, ultimately, some vegetation will establish. Since active site management is not acceptable, a chemical or physical root barrier should be included as part of the cover.

Chemical root barriers, although expensive, work well in cold climates and are likely to have a significant lifespan. A more common root barrier would be a physical barrier, consisting of a layer of gravel and cobbles filled with fines such as the candidate cover soils. The fines will prevent the layer acting as a capillary break. This root barrier should be at least 20 cm thick and should be above the barrier layer or, alternatively, below the store-and-release cover layer.

The root barrier will serve a secondary purpose of acting as a bio-intrusion layer preventing burrowing animals from penetrating the underlying waste. A root barrier needs to be constructed at Minto if low infiltration covers are required and active vegetation management is not being proposed.

2.15 Animal Activity

Minto is in a wilderness area and, therefore, after closure terrestrial animals are expected to move across the site. Burrowing activity by animals could compromise the cover, and to prevent such an occurrence, a gravelly layer can be designed into the cover. The likelihood of large scale damage due to animal burrowing action is very small and, therefore, such measures are not recommended at Minto.

2.16 Human Activity

Following closure, the site is likely to be infrequently used by seasonal hunters. Hunters typically use snowmobiles and all-terrain vehicles to get around and these machines can erode away the vegetation layer of a cover and subsequently result in damage to a geosynthetic liner. This can be mitigated by limiting access to the covered areas or, alternatively, adding in a coarse rock protection layer to the cover. The site is, however, sufficiently remote that concentrated access routes from these off-road vehicles are not expected and therefore no specific design elements will be included to protect against such damage.

3 Generalized Cover Types

3.1 Water Covers

Water covers involve permanently submerging mine waste. A water cover effectively shuts down oxygen ingress to the underlying waste, preventing oxidation. The water cover provides a constant hydraulic head that promotes seepage which may provide a pathway for mobilizing soluble oxidation products present in the waste. Therefore, water covers work best if oxidation of the waste is prevented from starting in the first place. If the waste has already undergone significant oxidation, exclusion of oxygen through a water cover to prevent further oxidation may not be warranted, or even desirable, given the inventory of oxidation products already present in the waste.

Water covers are best suited to net positive climatic water balance areas (i.e., annual precipitation exceeds evaporation), since that implies a surplus supply of water to the cover. Water covers are less favourable when permanent large engineered water retaining structures are required, such as dams that may be subject to long-term integrity concerns.

Based on the diffusion coefficient of oxygen through water, it is accepted that under ideal conditions only 30 cm of water cover would be sufficient to prevent oxidation. In reality, waste disposal facilities are typically large, and are subject to wind induced wave action, counter-current flows, seiching, lake/pond turnover (and lake/pond ice formation in cold climates) etc. These physical actions result in water turbulence, which in turn, may result in re-suspension of particles. Re-suspended particles may undergo oxidation rendering the water cover ineffective. Rules-of-thumb state that a 1 m thick water cover would mitigate against these concerns; however, a review of current practice shows that typical water cover depths are between 2 and 5 m thick.

As described in Section 2.2, the climate at Minto is conducive to the use of water covers. The mine waste at Minto is however not highly oxidizing and therefore maintaining a permanent water cover is not necessary for long-term geochemical stability. More importantly however is the fact that, with the exception of tailings deposited in Main Pit (and possible future pits), the mine waste rock and dry-stack tailings facility cannot readily be flooded unless large containment structures are constructed, and/or waste is relocated. For the tailings in Main Pit, a water cover could likely easily be engineered; but a perpetual water retaining dam would be required. Water covers were, therefore, not given further consideration at this time.

3.2 Saturated Soil Cover

Saturated soil covers are an alternative method of ensuring isolation of wastes from exposure to oxygen, but by eliminating the need for large stretches of open water, the issues associated with re-suspension are eliminated. The concept entails using a coarse (ideally gravelly) material with significant void space as the primary cover material and placing it in a perpetually saturated state. This saturated layer can be at surface or at depth, i.e., providing opportunity for an upper cover layer that may, for example, sustain vegetation. This type of cover works best if the climatic water balance is positive, and just as with the water cover, may be problematic if significant oxidation products are already present.

At Minto this type of cover may have merit for in-pit tailings although, given the fact that neutral metal leaching is a concern, the constant hydraulic head and subsequent risk of seepage may be problematic. Therefore this cover type was not explored further at this time.

3.3 Barrier Covers

3.3.1 Concept

Barrier covers (also known as water shedding or infiltration controlling covers) work on the principle of physically limiting and/or preventing meteoric infiltration and/or oxygen ingress. As described above, if the waste has been significantly oxidized, an oxygen barrier may be of limited benefit; however, a cover controlling infiltration may be of benefit.

Physical barriers can come in many different forms, including impermeable synthetic barriers such as high density polyethylene (HDPE) liners, low density polyethylene (LDPE) liners, bituminous liners, geosynthetic clay liners (GCL), or natural low permeability soil. A barrier cover can also be constructed by amending the surface layer of mine waste to achieve a low permeability layer. A brief summary of these different barrier cover types is provided below.

3.3.2 Natural Low Permeability Soil Cover

The effectiveness of a natural low permeability soil cover is determined by the following criteria:

- The cover should have a sufficiently low saturated hydraulic conductivity in order to restrict meteoric infiltration rates to the underlying waste;
- The cover should have a significantly lower saturated hydraulic conductivity than the underlying waste; and
- The cover should maintain a high degree of water saturation in order to limit the entry of atmospheric oxygen to the waste (a rule of thumb is at least 85% saturation).

A natural low permeability soil cover that is intended to act as both a water and oxygen reducing cover should adhere to all criteria above, whilst if the cover is only required to act as an infiltration barrier it needs to only adhere to the first and second criteria. If the intent of the cover is to act as only an oxygen barrier, it needs only to adhere to the third criterion.

Natural low permeability soil covers work best in net positive water balance climates which are not subject to freeze-thaw cycles. Under such conditions, there is sufficient moisture to keep the level of cover saturation high, and cover degradation due to frequent wetting and drying cycles (i.e., shrinkage and cracking) is limited. The annualized climatic water balance at Minto is largely net positive; however, three months of the year it is net negative, and more importantly, the site is subject to annual ground freezing. Therefore, if the barrier layer can be constructed below the annual depth of freezing, a barrier cover would likely work well at the site.

Generally, natural low permeability soil covers consist of clays and silts, with plasticity ranging from moderate to high. These materials are generally placed in a compacted state. Theoretically, a low permeability cover does not have a minimum thickness, i.e., the performance of a 1 m thick layer with a specific saturated hydraulic conductivity value would have exactly the same net effect as a geosynthetic clay liner (GCL) of the same saturated hydraulic conductivity given the same hydraulic gradient (i.e., unity). In practice, however, low permeability layer thickness is governed by constructability and allowance for desiccation cracking. Therefore, if the low permeability cover: (a) has limited desiccation cracking risk due to a well-graded texture and low plasticity, (b) is not subject to extreme wetting and drying cycles; (c) is below the depth of ground frost penetration; and, (d) is protected against surface runoff erosion, then the cover could be relatively thin, and constructability issues would be the primary concern (i.e., it is difficult to place a consistent thin compacted layer of low permeability soil over an undulating waste pile surface, and it is almost impossible to do so on soft saturated ground).

It is generally considered poor practice to allow vegetation to establish directly on a compacted low permeability layer because the design hydraulic conductivity and performance will be compromised. If a single-layer cover is adopted, using only the compacted low permeability cover material, then the thickness must be appropriately increased to allow at least a 60 cm thick layer of compacted low permeability soil that will not be penetrated by roots. As an added safeguard, consideration can be given to placing a root barrier. At Minto, use of a single layer at surface is not recommended due to ground freezing.

In order to get a general sense of what type of cover material would be required to perform as an effective natural low permeability soil cover at the Minto site, some general calculations can be carried out. Infiltration due to precipitation will be reduced if the hydraulic conductivity of the soil cover profile is less than the intensity of precipitation. For example, if the annual precipitation at Minto is about 335 mm, or 1.06×10^{-8} m/sec, water infiltration will be limited should the hydraulic conductivity of the cover be less than this value. Therefore, if it is intended to reduce infiltration through the cover to less than 20% of mean annual precipitation (i.e., less than 67 mm), the cover material should have a saturated hydraulic conductivity of at least 2.12×10^{-9} m/sec. From a water infiltration perspective, this a conservative assessment, since in reality the cover would not be completely saturated all the time, and based on unsaturated soil property theory, the hydraulic conductivity of an unsaturated soil profile is significantly less than in its saturated state. However, if the profile is significantly de-saturated to benefit from a low unsaturated hydraulic conductivity, the soil air entry value will be exceeded, and significant oxygen ingress will occur, i.e., the cover cannot be an oxygen barrier.

Current soil characterization data suggest that the saturated hydraulic conductivities of the available candidate cover materials range from 1.99×10^{-7} to 1.12×10^{-7} m/sec (6,275 to 3,532 mm/year), which is clearly not suitable for use as a barrier cover. Experience has shown that in practice, it is not realistic to expect natural soil barrier covers to have saturated hydraulic conductivities of less than 10^{-7} m/sec (about 3,154 mm/year), even though laboratory tests would often suggest otherwise. This is especially true if the barrier layer is located within the soil active zone (i.e., it is within the zone of cyclic wetting and drying, or freezing and thawing). Furthermore, Wilson *et al*. (2003) demonstrate that world wide experience with natural soil barrier covers, especially in seasonally wet/dry climates almost always yield greater than expected or predicted infiltration numbers. Given the site climatic conditions, SRK would not recommend the use of natural soil barrier covers at Minto using the locally available soils.

3.3.3 Synthetic Cover (HDPE, LDPE, Bituminous Liner)

Low permeability soils, if available, are almost always more economical than synthetic products; however, when natural soils are not readily available, or if the environmental risk is high, synthetic products such as capping materials can be appropriate. HDPE, LDPE, and bituminous liners are essentially impermeable; however, due to manufacturing and installation errors, even under the best quality control procedures, small pin holes can develop in the liner, such that generally for design purposes these liners are assumed to have saturated hydraulic conductivity values in the order of 10^{-15} m/sec (0.00003 mm/year). The difference between HDPE, LDPE, and bituminous products is generally the chemical resistance and workability of the material, with HDPE and bituminous liners being more robust products.

Synthetic liners must be installed according to manufacturer installation procedures that call for seaming of joints between liner sections, as well as placing the liner on an appropriately prepared surface. An appropriately prepared surface implies a clean, stable, smooth surface with limited undulations and few surface protrusions. If the waste surface is sufficiently coarse, the liner may be damaged, and an appropriate bedding material consisting of either a layer of clean sand or a non-woven geotextile are required.

Finally, the liner would have to be covered with a suitable cover depending on the final adopted land use. Again, if the cover soil contains a significant coarse fraction, then a protective sand or geotextile layer must first be placed over the liner.

An HDPE, LDPE, or bituminous liner would effectively eliminate oxygen and water ingress and provide a reclamation alternative with the least risk of impacting the environment in the long-term. Synthetic liners do, however, have a finite lifetime (manufacturer's guarantee is normally limited to about 20 to 40 years), and there is a possibility that the closure plan would have to allow for complete liner replacement every 100 to 200 years. Finally, synthetic liners cannot be constructed on steep slopes, with the general rule of thumb being slopes flatter than 3H:1V for short slopes, and as flat as 5H:1V for longer slopes. If low infiltration covers are required at Minto, these types of covers should be considered.

3.3.4 Synthetic Cover (Geosynthetic Clay Liner)

A GCL consists of a thin layer (generally less than 1 cm thick) of bentonite clay sandwiched between two non-woven geotextile layers. Under ideal conditions, a GCL is generally assumed to have a hydraulic conductivity of approximately 10^{-11} m/sec (0.3 mm/year); however, in practice a value of 10^{-9} m/sec (31.5 mm/year) is often adopted for design calculations. GCLs are considered to be less susceptible to installation damage than HDPE, LDPE, or bituminous liners; however, they must be installed according to manufacturer's installation procedures. Since GCLs are generally used with liquid containment in mind, and the use of a GCL as a cover (infiltration barrier) is somewhat different, the sub-grade specification can be relaxed. Depending on the surface preparation, it is conceivable that the GCL may be placed directly onto the mine waste and similarly the protective cover could be placed directly onto the GCL. The built-in geotextile, if appropriately specified, may provide sufficient protection.

A cover which includes a GCL may prove to be an extremely effective infiltration and oxygen barrier, provided the bentonite can remain hydrated and confined at all times. At the Minto site, this hydration should not be a problem during the wet season, but during the dry season, the bentonite may de-hydrate if the protective layer does not have sufficient moisture retaining capability. In addition, if the GCL is subject to freeze-thaw cycles, the physical integrity of the liner may be impacted. A GCL can be penetrated by roots, and therefore, as with a natural low permeability soil cover, it is desirable to ensure the vegetative substrate is thick enough to ensure roots do not reach the GCL, or alternatively, introduce a root barrier into the cover design.

It is also important to carefully consider the calcium content of meteoric water that will permeate through the GCL. As water passes through the GCL, calcium will cause ion exchange with sodium in the bentonite, which leads to permanent aggregation of the GCL. This results in an increased hydraulic conductivity, and subsequently increased infiltration rates (Lin and Benson 2000).

GCL covers are worth considering at Minto if low infiltration covers are required.

3.3.5 Bentonite Amended Mine Waste/Cover Soils

It is possible to reduce the surface hydraulic conductivity of the mine waste or a candidate cover material by mixing in bentonite clay and compacting the mixed layer, thereby creating an in-situ low permeability layer. This type of amendment is often done as a more cost effective solution than a synthetic cover to reduce surface permeability due to the fact that limited importing of soils and/or synthetic products is required. The hydraulic conductivity is reduced by mixing in bentonite clay which has a high affinity for moisture and hydrates to more than twice its volume, thereby taking up void space in the host material, which would otherwise have a high hydraulic conductivity. Naturally the same restrictions apply to bentonite amended soils with respect to possible aggregation of the bentonite as a result of ion exchange as has been previously discussed for GCLs.

There are two primary methods to mix the bentonite and host soil (or mine waste): (a) off-site mixing using a pug mill, and (b) in-situ mixing. Off-site mixing requires stockpiles of host material and bentonite, which is fed into a pug mill, and the mixed product is trucked to the deposition location for application and compaction. This method allows for excellent control over the mix, including moisture control which is important to ensure proper hydration of the bentonite (the mix is normally placed at above optimum moisture content). In-situ mixing requires the upper layer of the location to be ripped before spreading the bentonite at the desired application rate.
The bentonite is then mixed into the host soil using agricultural equipment. This method allows for less control over application rate and moisture, and therefore requires more bentonite product. However, if the host material is not pre-stockpiled then this method is usually more cost-effective.

The thickness of the bentonite amended layer will be site specific; however, a realistic thickness for use as a low permeability cover would be between 15 cm and 30 cm thick, with an application rate of 4 to 6% bentonite by weight (of the host soil). The bentonite-amended layer will perform as an effective low permeability layer, reducing infiltration and oxygen ingress as long as the bentonite remains hydrated. Should the layer be allowed to dry out, the volume change will result in cracks, which will increase the hydraulic conductivity. Bentonite does however have self-healing characteristics which will help cracks to reseal if the bentonite becomes re-hydrated. Normally, to minimize chances of drying of the bentonite amended layer, it would be overlain with 50 cm of compacted, but non-modified material that would remain at high saturation due to the low permeability of the bentonite amended layer. Should vegetation be a requirement, a suitably designed vegetation substrate layer would have to be placed on the amended and compacted layers, to limit root penetration of the amended layer. Bentonite amended covers would be a worthwhile alternative to consider at Minto should low infiltration covers be required.

3.4 Store-and-Release Cover

An alternative method of reducing infiltration is to make use of the inherent soil moisture storage capacity of the soil. Meteoric infiltration is not prevented as with a barrier cover, but rather promoted, such that the moisture is stored in the cover soil. This moisture is returned to the atmosphere via evapotranspiration before is has the opportunity to drain through the cover and enter the underlying waste. These covers are referred to as “store-and-release” covers (also called “water retention” or “alternative” covers), and work most effectively in dominantly net negative climates, i.e., the potential evaporation greatly exceeds the mean annual precipitation (typically at least two or three times greater).

As discussed in Section 2.2, the site climate is not particularly well suited towards use of store-and-release covers; however, during the summer months, they certainly can be effective provided that the wet (frozen) season precipitation is shed as runoff, such that the amount of infiltration for which storage would have to be created, would be manageable. It may also be beneficial to provide a barrier layer beneath the store-and-release layer to prevent breakthrough during the prolonged wet season.

Ideal store-and-release cover soils are well-graded soils that have sufficient fines to allow capillarity to be high whilst not compromising too much on the material porosity. Store-and-release covers are less susceptible to site preparation and quality control since compaction of the soil cover is generally not required (or in fact not recommended) and the cover is of sufficient thickness to mask minor undulations on the waste surface. Settlement of the waste will also not affect the cover as much. Direct re-vegetation of the store-and-release cover is generally undertaken, unless the soil has a nutrient deficiency. The successful establishment of vegetation on a store-and-release cover is crucial towards its success, since the enhanced evapotranspiration will ensure long-term cover performance.

Notwithstanding the reservations about the applicability of using store-and-release covers at Minto, we can use the estimated hydraulic properties of the available cover soils at Minto, and use empirical methods (Chen 1999) to estimate the likely range of store-and-release cover thicknesses that would be required at Minto. Assuming 20% mean annual precipitation as the infiltration target, the store-and-release layer thickness would have to be between 384 and 740 mm. This increases to between 676 and 1,225 mm if the infiltration target was lowered to 2%. It is important to note that due to the relatively low air entry value of these soils, their capillarity is limited and, therefore, increasing the thickness of the store-and-release layer provides very little added benefit. Although the available storage space is increased, the moisture cannot be moved upward more than about 1 m at most, but more importantly, there is not enough radiating energy available to extract the excess moisture.

At Minto, considering the available soils and climate, an infiltration target of about 20% on average for a store-and-release type cover is probably as good as would be consistently attainable. Under specific conditions this cover is likely to yield much better performance; however, significant breakthrough events will frequently occur.

3.5 Reactive Cover

Reactive covers normally refer to covers that include chemically active components. Broadly speaking, two types of such reactive covers are referred to: (1) covers where the reaction leads to consumption of oxygen, and (2) covers where the reaction leads to formation of low permeability layers and/or barriers to oxygen diffusion.

Oxygen consuming covers can be either organic or inorganic. Organic covers, for example wood waste over an acid generating tailings impoundment have been shown to have good success, however the main complication with these kinds of covers is that they are not sustainable. The organic cover loses its ability to consume oxygen over time, and as a result become ineffective. Organic oxygen consuming covers can be in the form of materials that have high neutralizing potential, and as a result, balance out the overall seepage waste load as a result of the buffering capacity.

The concept of deliberately placing reactive materials to create low-permeability covers rests on the principal that two layers are placed in contact, each one being a reagent. Where these layers contact each other, the reactants will meet and combine to form a precipitate that fills the pores.

Although in theory reactive covers show potential, to date they have not been used in full scale mine closure applications. Some long-term and medium scale pilot scale covers have been constructed; however, the principle of using reactive covers as final closure covers has not been adopted by the industry to date.

There does not appear to be any potential cover materials that would make for good reactive cover construction at the Minto site, and therefore this type of cover was not given further consideration in this evaluation.

3.6 Capillary Break Cover

A capillary break cover can be used to limit infiltration and to prevent contaminants from a waste deposit from being wicked up into the cover soil. It works by placing a fine grained soil over a coarse soil (typically a gravely soil containing little or no fines). The upper fine soil can come close to saturation, before it allows flow to pass through the underlying gravel. Generally, if a capillary break is used to limit infiltration, it can be used to reduce the thickness of an overlying store-and-release cover layer.

A capillary break may also be useful to maintain a high degree of saturation in a cover such that it would act as an oxygen barrier. Therefore, a capillary barrier may be constructed under a low permeability cover layer to ensure that the degree of saturation remains high, and limit oxygen ingress.

Capillary barriers also work in the reverse, i.e., if there is an upward flux through the cover due to evaporative action through which contaminants in the waste body may be wicked to the surface, the capillary break will prevent this from happening. Such wicking could result in surface water contamination in runoff from the cover, and it could also lead to metal uptake of vegetation established on the cover. Wicking is generally more of a concern in a net negative climate, where the upward flux often dominates. This may only be a concern during the three dry months at Minto.

Assuming the capillary barrier has been correctly designed with the appropriate hydraulic properties (it must have a residual suction which is lower than the air entry value of the overlying fine soil), a capillary break layer has no minimum thickness. In reality, the rule of thumb is to design these layers at least 30 cm thick. Depending on the difference between the gradations of the capillary break and the overlying fine soil, a filter media or geotextile may be required at the upper and lower interfaces.

In many cases, the waste material to be covered is sufficiently coarse that, if a low permeability cover is applied, the gradation difference is sufficiently large enough that the waste itself would act as a capillary break. Capillary break covers are quite complex to design and construct, but are best used to either keep an upper or lower layer at a higher degree of saturation, or to specifically prevent upwards wicking. Neither of these conditions appears to be specifically required at Minto and therefore this cover variant was not considered further at this time.

3.7 Frozen/Thermal Cover

In cold regions, mine waste may freeze, or measures can be implemented to promote freezing. This effectively eliminates any risk of contamination from these wastes. Covers can therefore be designed to preserve the frozen waste mass. This concept, generally, only works in areas where cold continuous permafrost is already present and the covers are normally very thick (i.e., in excess of 2 m).

Minto is located in the discontinuous permafrost region of Canada and the permafrost present is relatively warm (i.e., about -1^{o}C near surface). Considering climate change predictions which are forecasting warming trends, design of a frozen cover at Minto is not considered a viable option.

4 Conceptual Cover Designs

4.1 Site Wide Closure Objectives

In accordance with the D&RP (Minto 2011), the site wide closure objectives are as follows:

- Have a closure planning process that seeks input from the Selkirk First Nations, understands the input received, and incorporates the input into closure planning decisions;
- Protect the health of people pursuing traditional activities including hunting, fishing, trapping, camping, and collection of plants for food, medicinal or cultural purposes;
- Protect people from safety risks when they are pursuing traditional activities including hunting, fishing, trapping, camping and collection of plants for food, medicinal or cultural purposes;
- Protect the environment (including land, air, water, plants, animals fish and other environmental components and their interrelationships) from long-term effects caused by the mine activities and facilities;
- Return the mine site and affected areas to a state similar to surrounding lands so that people can pursue traditional activities the same as they did before mining, including hunting, fishing, trapping, camping, and the collection of plants for food, medicinal or cultural purposes;
- Protect the environment from long-term effects caused by post-closure access to the mine area;
- Protect the environment from effects of earthquakes, floods, climate change, and other natural events on related mine structures;
- Have effective management and control structures in place during operation, closure and post-closure to provide;
  - Adequate financial resources to carry out all closure activities including plan implementation and long-term activities;
  - Adequate flexibility during closure and post-closure to allow adaptation of activities in order to address unexpected performance and events; and
  - Consideration of the Company's long-term desire to —walk away” from the site under conditions acceptable to Selkirk First Nations and with adequate resources provided to address long-term requirements.
- Minimize long-term activities by ensuring long-term chemical and physical stability of mining components and disturbed areas;

- Confirm the effectiveness of closure measures by monitoring the site after closure;
- Undertake mine planning incorporating progressive reclamation;
- Provide short and long-term slope stabilization and erosion control on linear and non-linear disturbances;
- Ensure the long-term chemical stability of residual mining components and minimize their effects on water quality draining the property;
- Ensure the long-term physical stability of key structures such as the waste dumps and the diversion and drainage ditches; and
- Work towards a passive closure scenario for most or all mine components.

4.2 Possible Cover Functions

Covers are one of many possible mitigation strategies that can be used to achieve site wide closure objectives. Other two common strategies include waste relocation and water treatment. If conditions are such that covers are a suitable mitigation strategy, then the specific function that the cover needs to perform in order to meet the closure objective must be explicitly stated. The following cover functions are recommended for Minto based on the current understanding of site conditions:

- Reduce infiltration to a specific target that would ensure site wide water quality objectives can be met;
- Isolate the mine waste to avoid direct contact by human or other terrestrial animals; and
- Provide a stable landform that is aesthetically pleasing.

4.3 Cover Design Criteria

The cover functions in Section 4.2 above could be considered ambiguous if they are considered in isolation and therefore these functions needs to be explicitly defined in terms of measurable design criteria. A set of example design criteria is provided in Table 4.1.

Table 2. Proposed Minto mine cover design criteria

Component	Criteria
Design Life	100 years (while it is recognized that the cover will remain in place for a longer period, design performance will be measured against this criteria)
Oxygen Reduction	Not required
Infiltration Reduction	Isolating Cover: no more than the uncovered waste; Low Infiltration Cover: no more than 10% of mean annual precipitation with no significant breakthrough events, and; Very Low Infiltration Cover: no more than 2% of mean annual precipitation with no breakthrough events
Waste Settlement	Waste Rock Piles and Dry-Stack tailings: no criteria; Main Pit Tailings: up to 30 cm on beach areas and up to 100 cm on slimes areas (cover is not expected to perform without maintenance and repair when subject to these settlements)
Seismicity	1 in 2,500 year recurrence interval (10% probability of exceeding in 50 years)
Trafficability	Concern for the Main Pit tailings area only. Mixing zone acceptable; but minimum cover design thickness to be measured from above the mixing zone
Physical Exposure	As far as practicable keep mine waste covered. In no areas may more than 1 m^2 of mine waste be exposed as a contiguous area for the life of the structure
Slope Stability	Overall factor of safety of at least 1.3 under static conditions and 1.1 under seismic loading
Wind Erosion	No visible dust up to and including wind speeds with a recurrence interval of 1:10 years, for any given duration. In no areas may overall cover thickness be less than 75% of original design thickness for the life of the structure
Overland Surface Runoff	Capable of withstanding 1:100 year, 24 hour duration storm during peak freshet with no damage. In no areas may overall cover thickness be less than 75% of original design thickness for the life of the structure
Evapo-Concentration	Not required
Root-Uptake	Not required
Vegetation	Self-sustaining vegetation cover endemic to the region within 20 years after cover construction (foreign species and fertilizers during early years acceptable if it supports the final objective)
Land Use	General wilderness area. Large terrestrial animals, birds and aquatic life will be present. Humans will travel through the area infrequently (mostly hunters and trappers). Specific measures to preclude damage to the covers due to human and/or animal use not required
Landform	Promote use of landforms consistent with the current landscape. Provide for variability on cover thicknesses and landscaping to promote establishment of microclimates and variability

4.4 Conceptual Designs

4.4.1 Isolating Cover

Figure 15 illustrates a conceptual isolating cover for the Minto site. The bottom trafficking layer of run-of-mine waste rock is only required for the Main Pit tailings. For beach areas, the trafficking layer thickness of about 0.5 m is probably sufficient, but in the slimes areas, this layer may have to be up to 1 m thick. It is recommended that these trafficking layers be constructed during the winter season when the tailings surface is frozen as the added strength will facilitate in minimizing the mixing zone which would reduce the total volume of material required. Note that tailings may migrate through the trafficking layer as traffic passes over the cover and therefore placement of this layer alone does not constitute an isolating layer.

The isolating layer will be a minimum 0.5 m thick compacted layer of local overburden soil. No specific measures need to be taken to specifically preclude compacting through trafficking across the covered surface; however, to the extent practical, to facilitate vegetation establishment, care must be taken to prevent excessive vehicle compaction. The soil cover will then be re-vegetated.

Detailed numerical analysis has not been carried out; however it is SRK’s opinion based on the material characterization and site climate that this cover would consistently result in infiltration values of between 10 and 20% of mean annual precipitation. Significant breakthrough events can, however, occur based on large individual rainfall events. The cover will be susceptible to surface erosion and, therefore, it would be of paramount importance to establish stabilizing vegetation soon after cover placement. Where surface runoff concentrates, dedicated surface water conveyance channels will have to be constructed.

The performance of this cover will not be affected by freeze-thaw and wetting/drying cycles and is not significantly affected by waste settlement. Some maintenance in the form of regrading will be required if significant differential settlement is experienced to ensure that water is not trapped in ponds on the covered surface.

4.4.2 Low Infiltration Cover

A conceptual low infiltration cover for the Minto site is presented in Figure 16. The locally available soils are not suited to constructing low infiltration covers and therefore soil amendment will be required. Although no specific testing has been carried out, it is expected that a 4% bentonite mix with the locally available soils will yield an appropriate infiltration barrier to ensure infiltration remains consistently below 10% of mean annual precipitation. The amended layer should be about 0.3 m thick, be compacted and covered with a 0.5 m loosely compacted isolating layer as described in Section 4.4.1.

The trafficking layer requirements are also consistent with those described in Section 4.4.1.

The infiltration performance of this cover will be affected by freeze/thaw and wetting/drying cycles; however the self-healing properties of the bentonite should compensate against total failure. It is, however, conceivable that small breakthrough events could occur unless the upper isolating cover is increased in thickness to about 3 m to ensure the amended barrier layer is below the annual frost penetration depth.

The cover performance is sensitive to waste settlement, as large displacements of the bentonite amended layer may result in significant discontinuities in the layer which would increase infiltration. Frequent inspections of the cover will have to be undertaken over the Main Pit tailings and where large depressions are observed, the bentonite amended layer must be exposed and possibly in-filled to compensate for potential loss of performance.

On the dry-stack and possibly the Main Pit beach areas, consideration can be given to amending the upper tailings surface with bentonite as opposed to the dedicated 0.3 m thick imported overburden layer.

Appropriate trade-off studies will have to be carried out to determine the most cost effective method of mixing the amended layer.

4.4.3 Very Low Infiltration Cover

Suitable natural soils to construct a very low infiltration cover at Minto are not available and, therefore, a geosynthetic liner is recommended if this level of cover performance is required. An appropriate trade-off study will have to be carried out to determine the most economical geosynthetic product; however, for the purpose of this study, a 60 mil textured HDPE liner has been assumed. The overall conceptual cover design is illustrated in Figure 17. As described before, the trafficking layer only applies to the Main Pit tailings impoundment.

A levelling and protective layer of compacted tailings (borrowed from Main Pit beach tailings or the dry-stack tailings impoundment) at least 10 cm thick must be placed between the mine waste and the liner. Note this is not required on the dry-stack, but will be required on the Main Pit tailings since the trafficking layer will be the surface on which the liner is placed.

A similar protection layer must be placed over the liner prior to constructing the overliner soil cover. Given the relatively benign geochemical composition of the tailings, it is recommended that this layer be tailings. Should focussed characterization prove this is unacceptable, suitable clean sand would have to be imported, or alternaticely a robust (e.g., 16 oz) non-woven geotextile can be substituted.

The overliner soil cover should consist of a 0.3 m thick compacted layer (at least 98% Standard Proctor) of local overburden soils, overlain by a 0.5 m thick, loosely compacted layer similar to that recommended for the isolating cover. The lower compacted layer serves to better anchor the liner, and to provide a root barrier to resist deep penetration which may damage the liner.

Although detailed numerical analysis has not been carried out, the liner, if installed with due care, will ensure infiltration to less than 2% of mean annual precipitation with no chance of breakthrough events due to extreme events. The upper isolating cover will be susceptible to surface erosion and would require the same treatment as described in Section 4.4.1.

The infiltration performance of this cover will not be affected by freeze/thaw and wetting/drying cycles; however the compacted layer will become less dense overtime, thereby reducing its functionality as described. A complete loss of functionality over the design life of the cover is, however, not expected.

The liner performance is very sensitive to waste settlement, and may tear or rupture under severe conditions. Frequent inspections of the cover will have to be undertaken over the Main Pit tailings impoundment in the first 5 to 20 years following cover construction. If trampolining (i.e., unsupported liner) is observed, the liner would have to be exposed, and remedial works initiated.

5 Conclusions

The hydrologic and climatic regime at the Minto site is best suited to the use of water covers or infiltration reducing covers (i.e., barrier covers). Store-and-release and thermal covers are not likely to be successful. The available overburden soils at Minto are not well suited for construction of low or very low infiltration covers.

These soils can however be used as effective isolation and vegetation supporting covers, and are expected to result in overall infiltration of between 10 and 20% of mean annual precipitation, typically. Periodic higher breakthrough events will, however, occur. Soil amendments or use of synthetic products would be required to construct low to very low infiltration covers at the site. Conceptual designs of each of these different cover variants have been proposed.

This report ***"Scoping Level Cover Assessment for Minto Closure Covers"*** has been prepared by:

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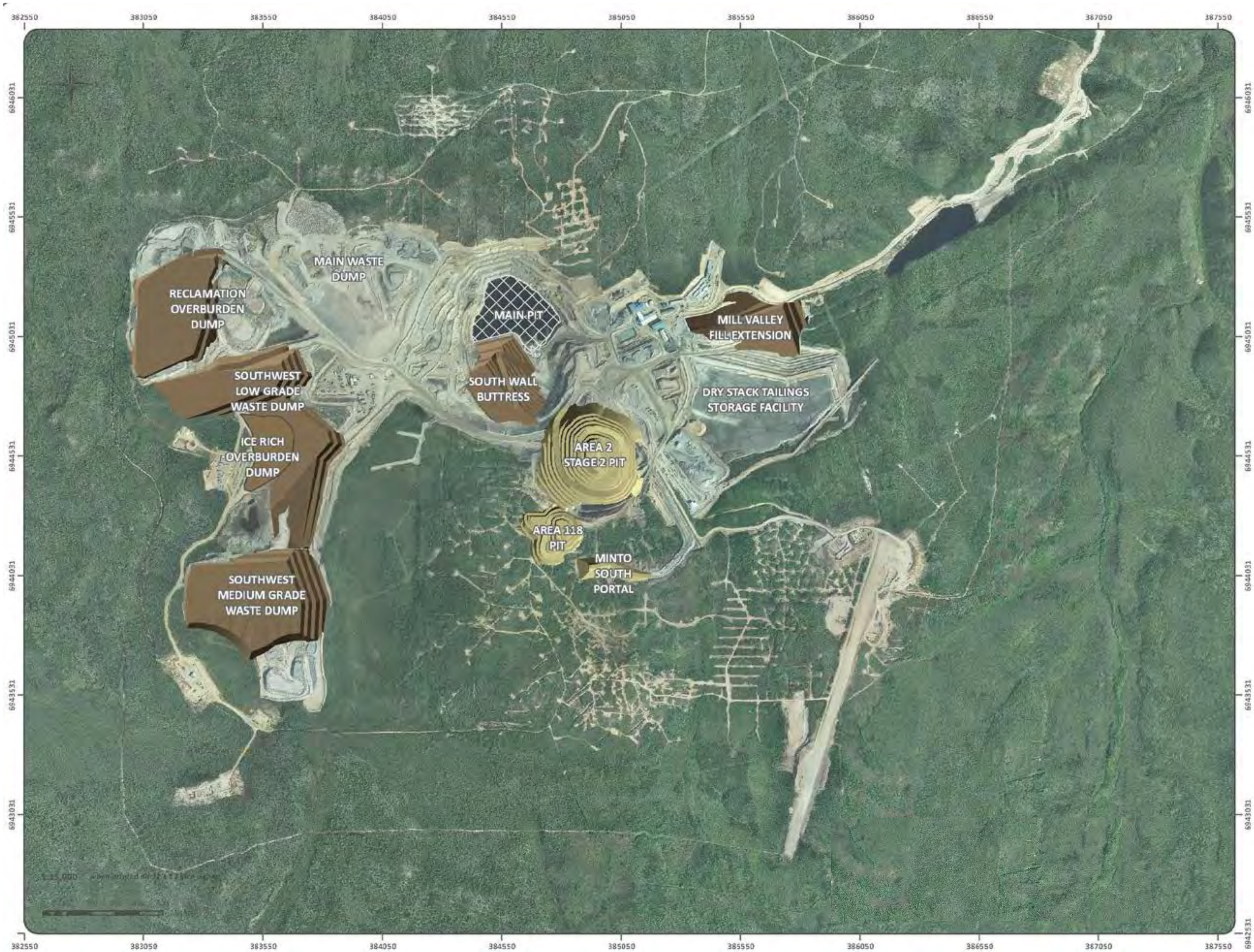
Figures



Note: Drawing as supplied by Minto Explorations Ltd. (subsidiary of Capstone Mining Corp.)

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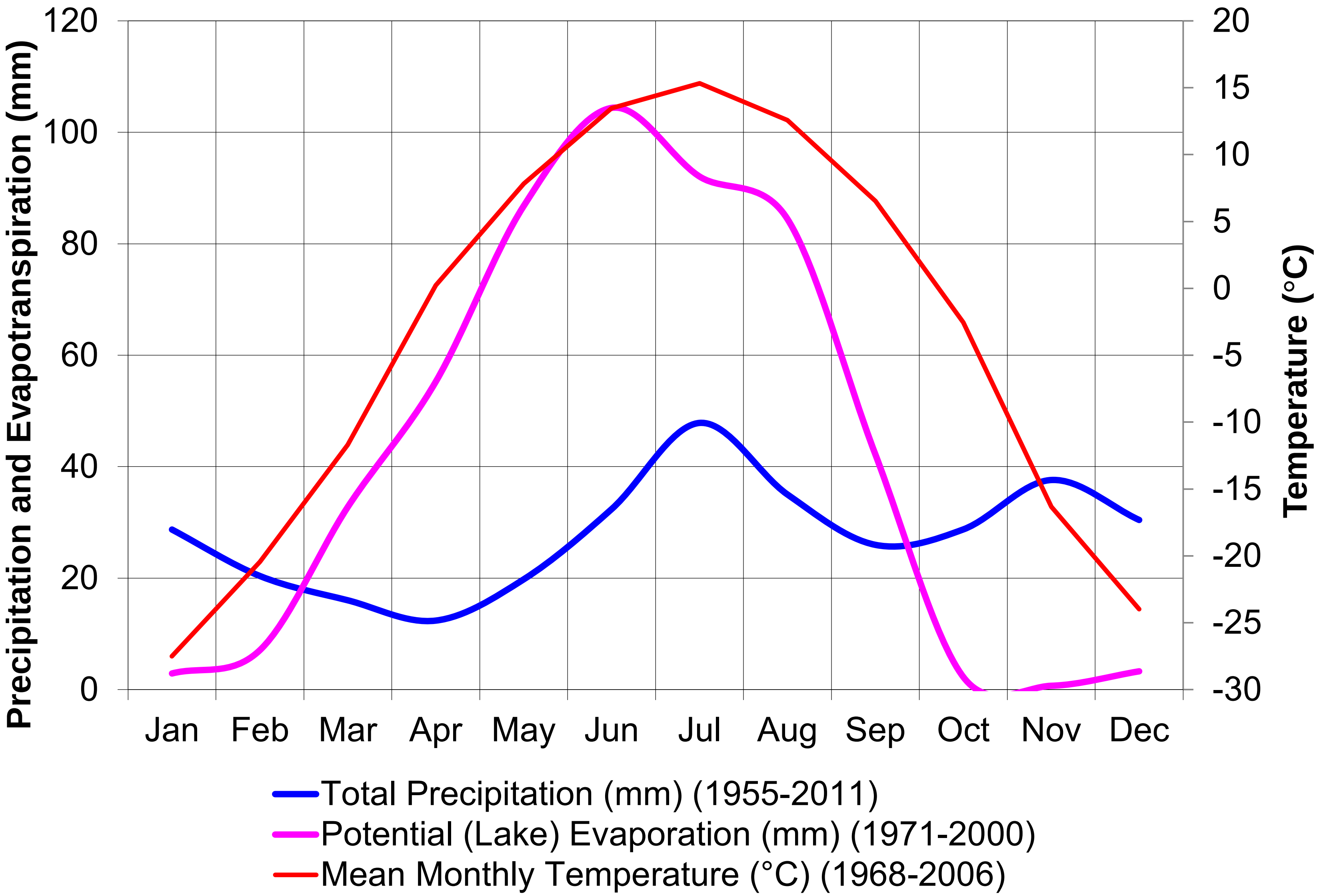
Scoping Level Cover Assessment

General Site Layout

Job No: 1CM002.007
Filename: Figure 1_1CM002.007_Gen Layout_Rev01.pptx

Minto Mine

Date:	Approved:	Figure:
July 2013	EMR	1



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srk consulting	CAPSTONE MINING CORP. MINTO MINE	Scoping Level Cover Assessment		
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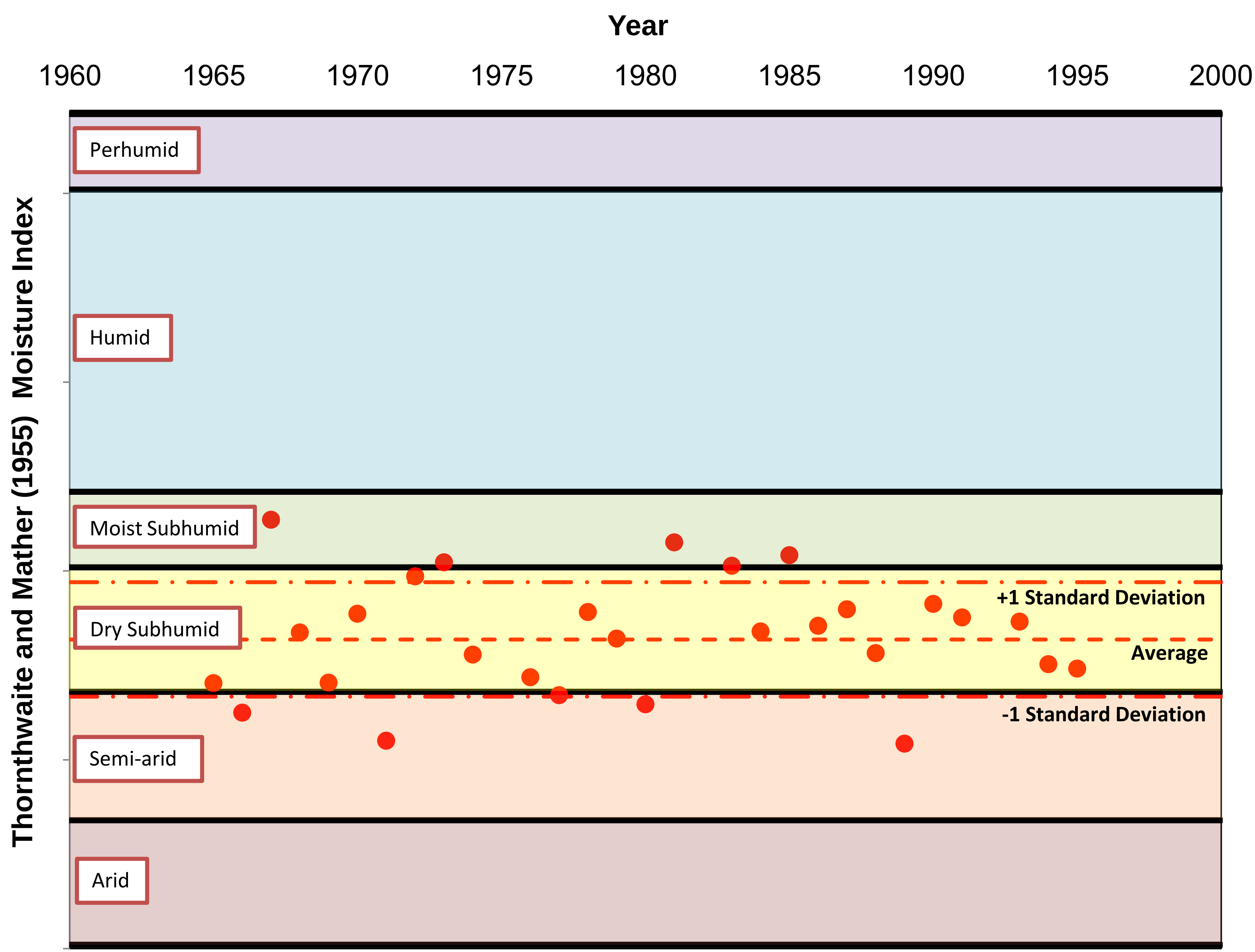

srk consulting	CAPSTONE MINING CORP. MINTO MINE	Scoping Level Cover Assessment **Thornthwaite & Mather (1995) Moisture Index**
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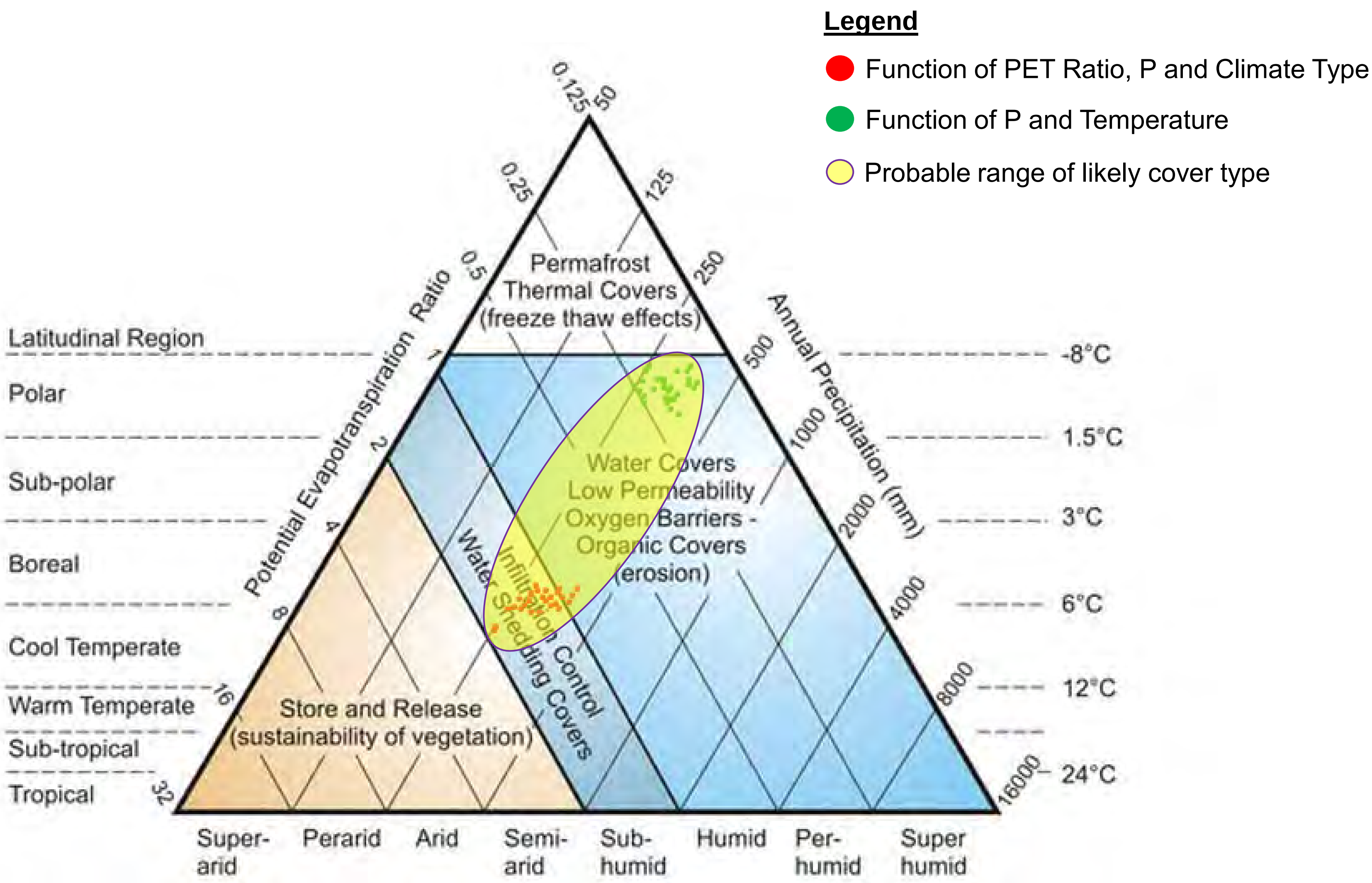

Chart obtained from:
Chapter 6 - GARDGuide. 2013. *Chapter 6 - GARDGuide*. [ONLINE] Available at: http://www.gardguide.com/index.php/Chapter_6. [Accessed 04 April 2013]. (Wickland and Wilson, 2006)

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Scoping Level Cover Assessment

Typical Cover Types

Job No: 1CM002.007
Filename: Figure 2-14_1CM002.007_Rev05.pptx

Minto Mine

Date: July 2013 | Approved: EMR | Figure: 4

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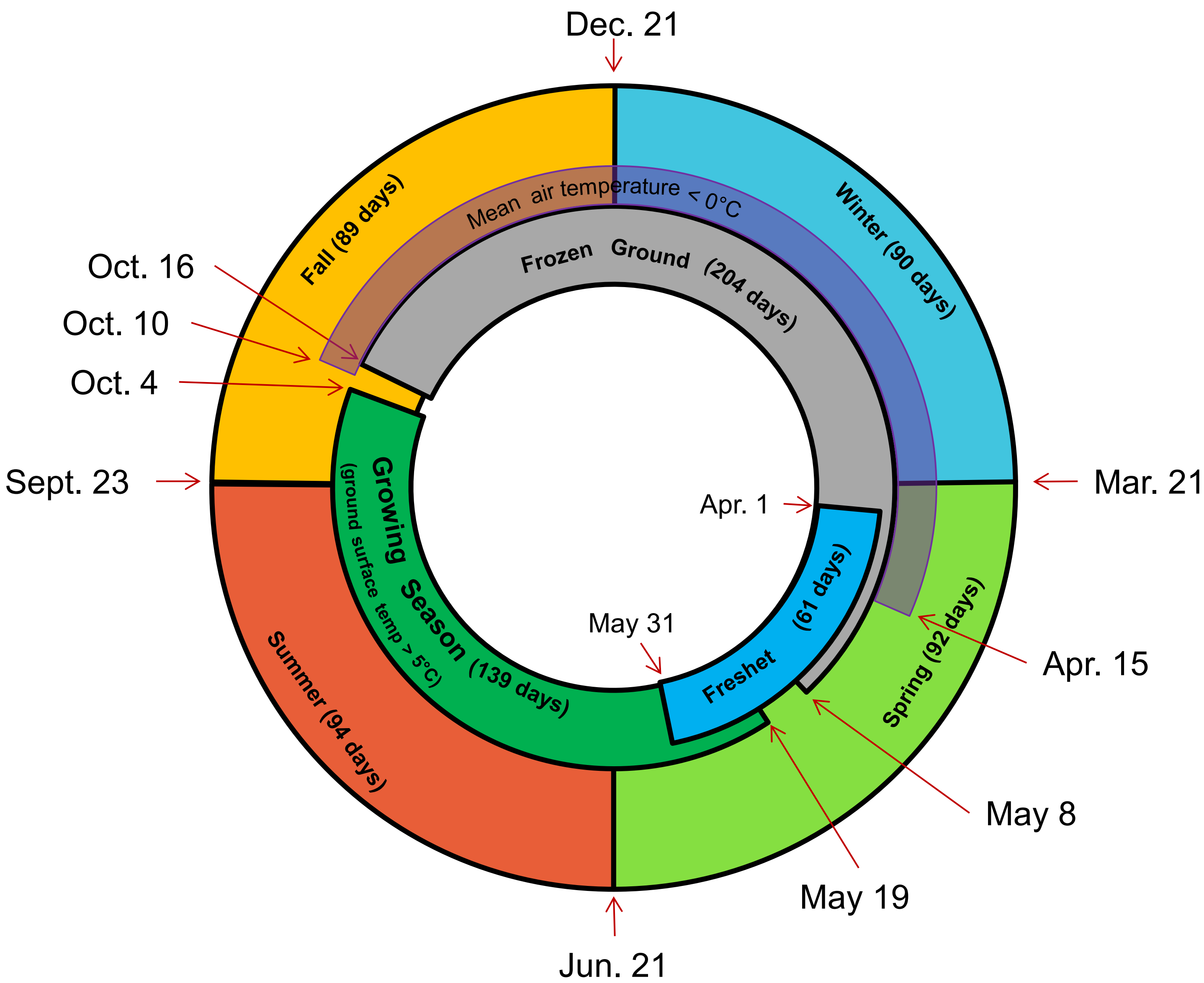

srk consulting	CAPSTONE MINING CORP. MINTO MINE	Scoping Level Cover Assessment
		Climate Wheel
Job No: 1CM002.007 Filename: Figure 2-14_1CM002.007_Rev05.pptx	Minto Mine	Date: July 2013 · Approved: EMR · Figure: 5

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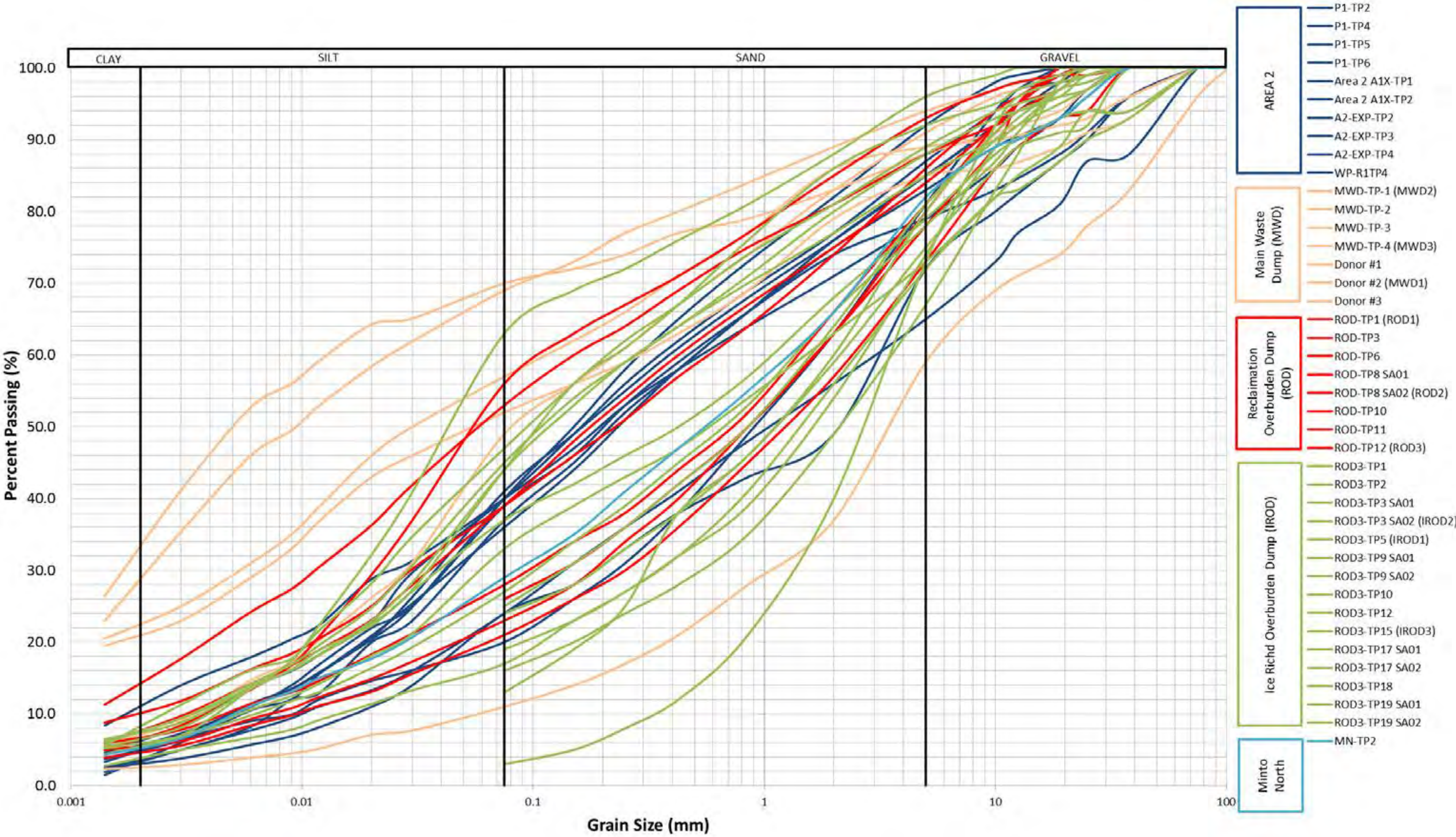

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Scoping Level Cover Assessment

Grain Size Distribution Curves for All Candidate Cover Materials

Job No: 1CM002.007
Filename: Figure 2-14_1CM002.007_Rev05.pptx

Minto Mine

Date: July 2013 | Approved: EMR | Figure: 6

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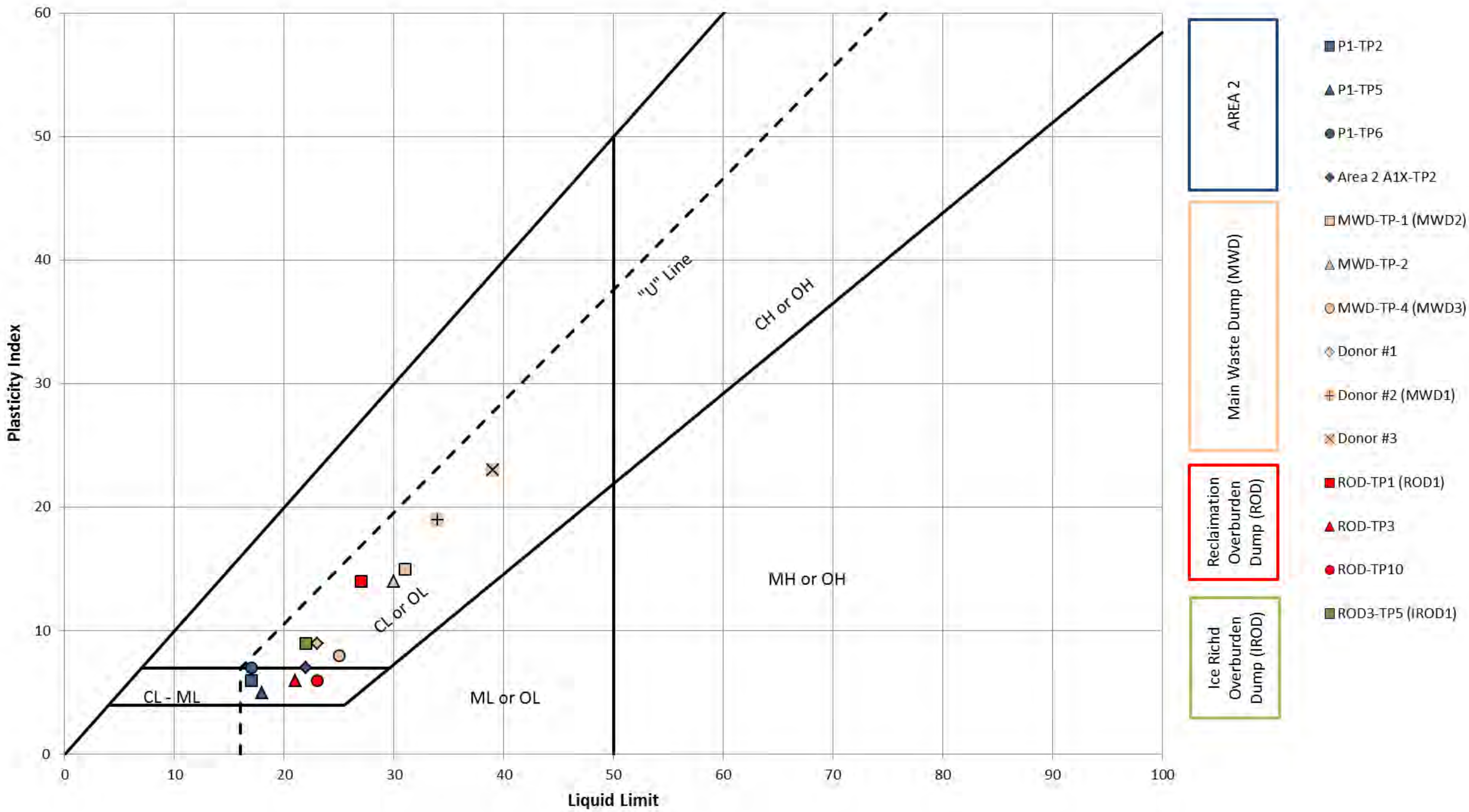

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Scoping Level Cover Assessment

Atterberg Limits for All Candidate Cover Materials

Job No: 1CM002.007

Filename: Figure 2-14_1CM002.007_Rev05.pptx

Minto Mine

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Figure: 7

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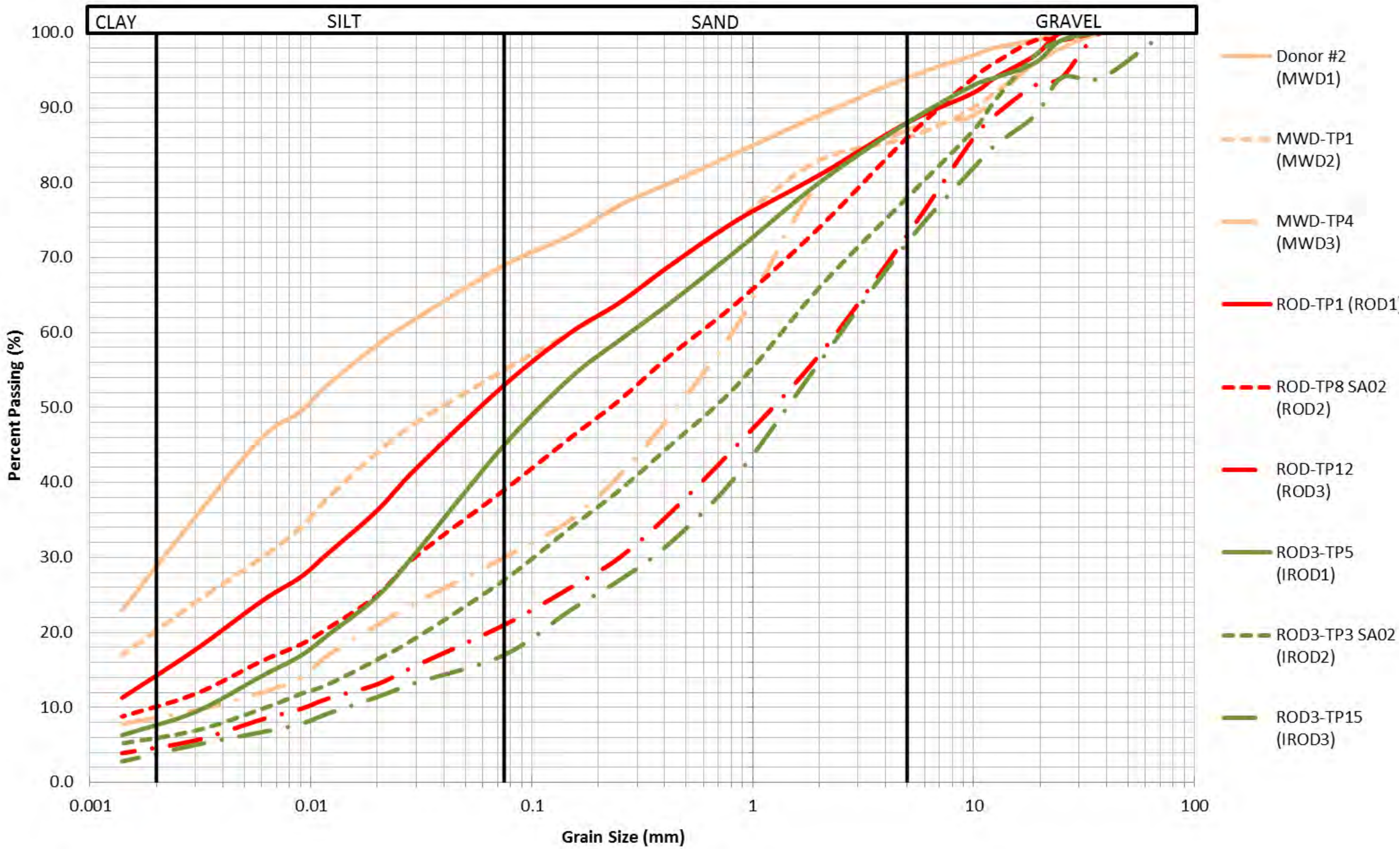

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Scoping Level Cover Assessment

Representative Cover Materials

Job No: 1CM002.007

Filename: Figure 2-14_1CM002.007_Rev05.pptx

Minto Mine

Date: July 2013

Approved: EMR

Figure: 8

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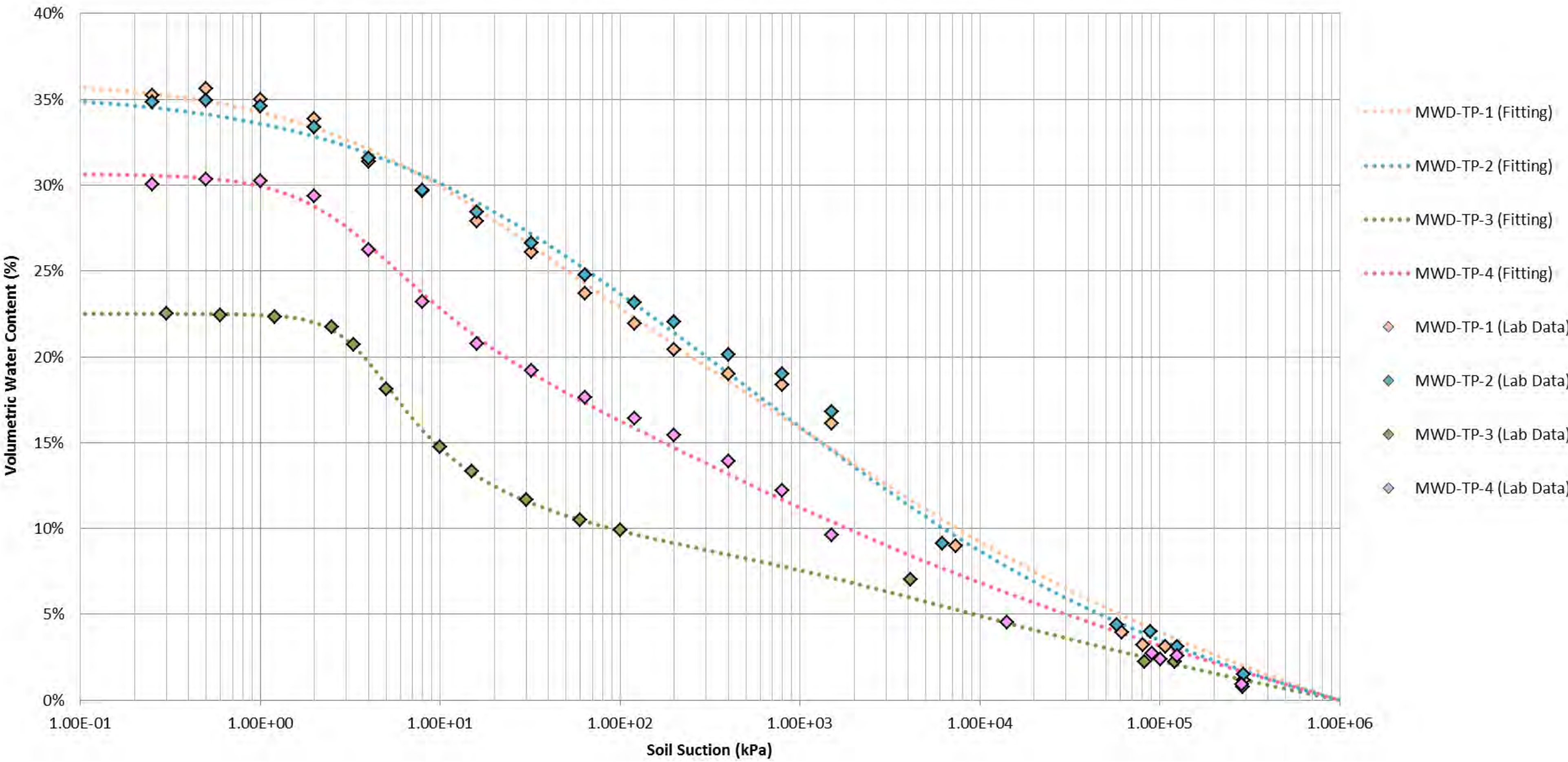

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srk consulting	CAPSTONE MINING CORP. MINTO MINE	Scoping Level Cover Assessment **Measured Soil Water Characteristic Curves**
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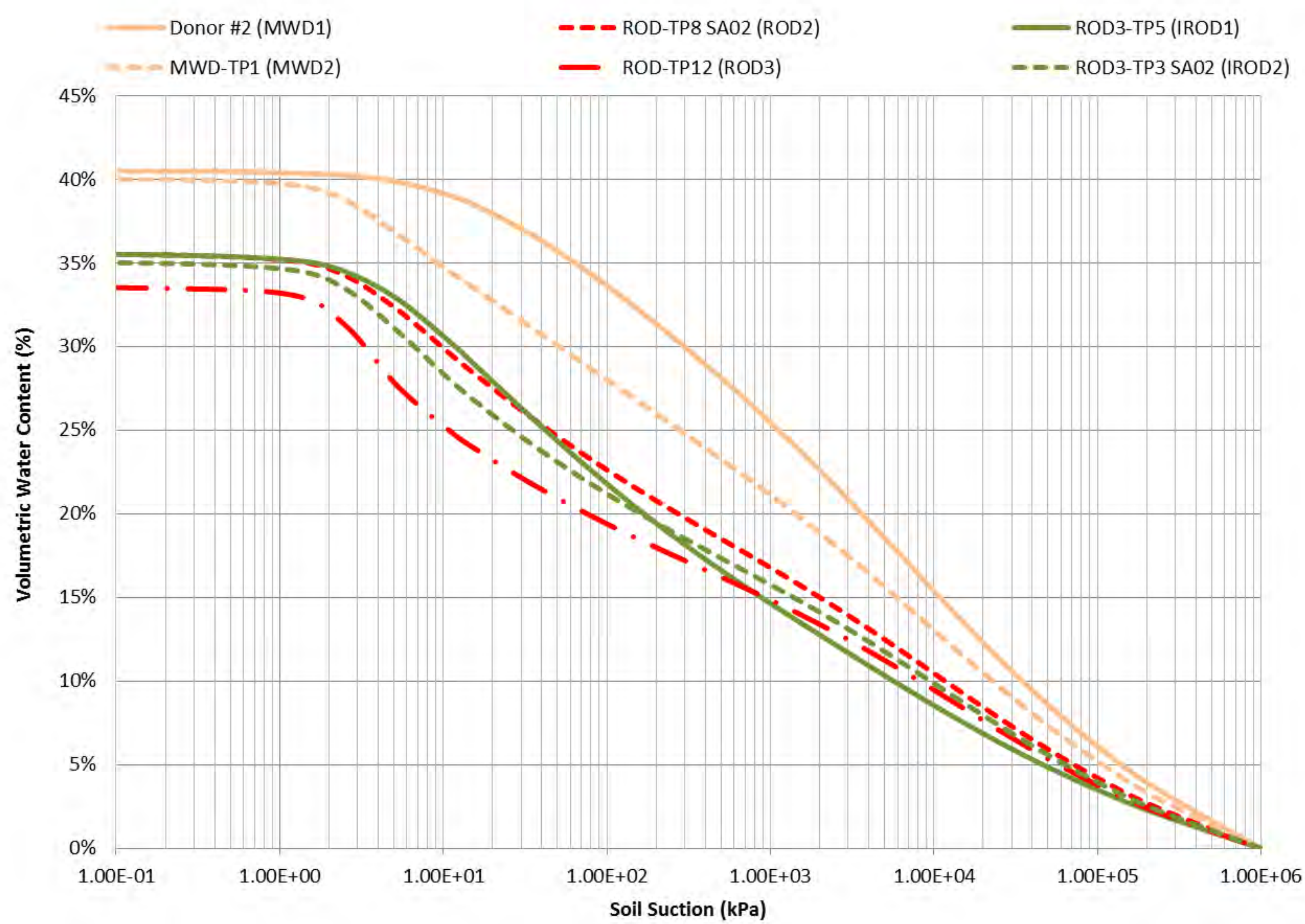

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Scoping Level Cover Assessment

Estimated Soil Water Characteristic Curves

Job No: 1CM002.007

Filename: Figure 2-14_1CM002.007_Rev05.pptx

Minto Mine

Date: July 2013

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Figure: 10

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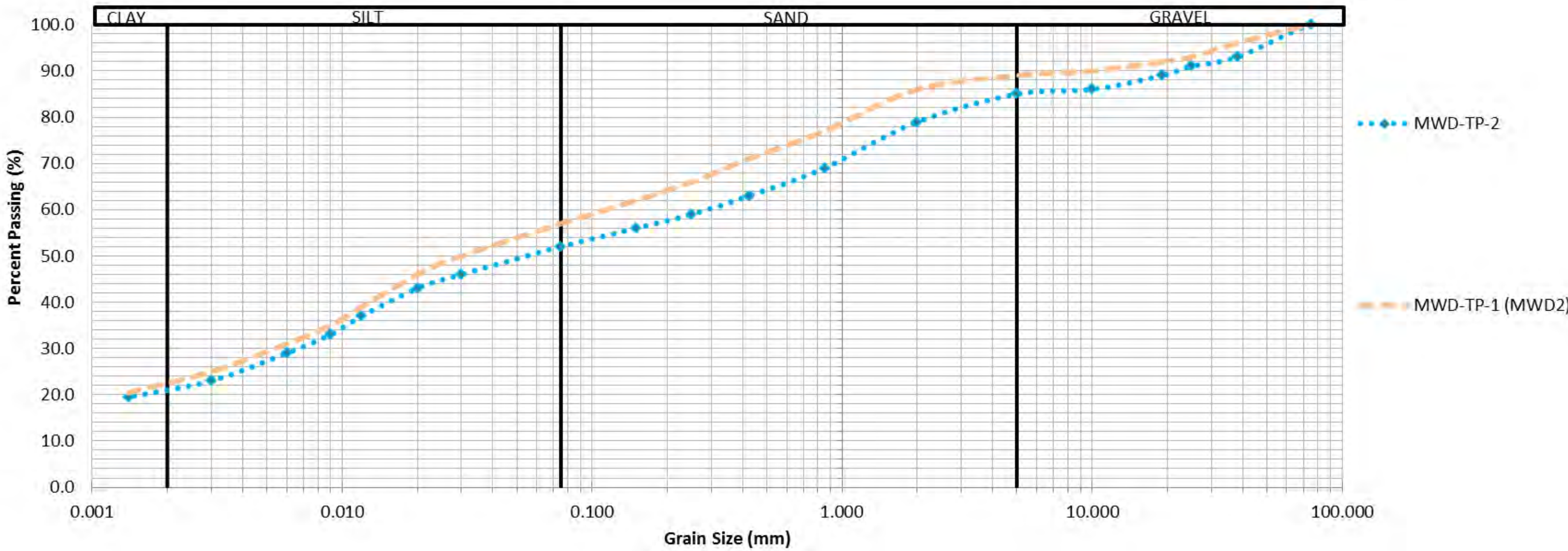

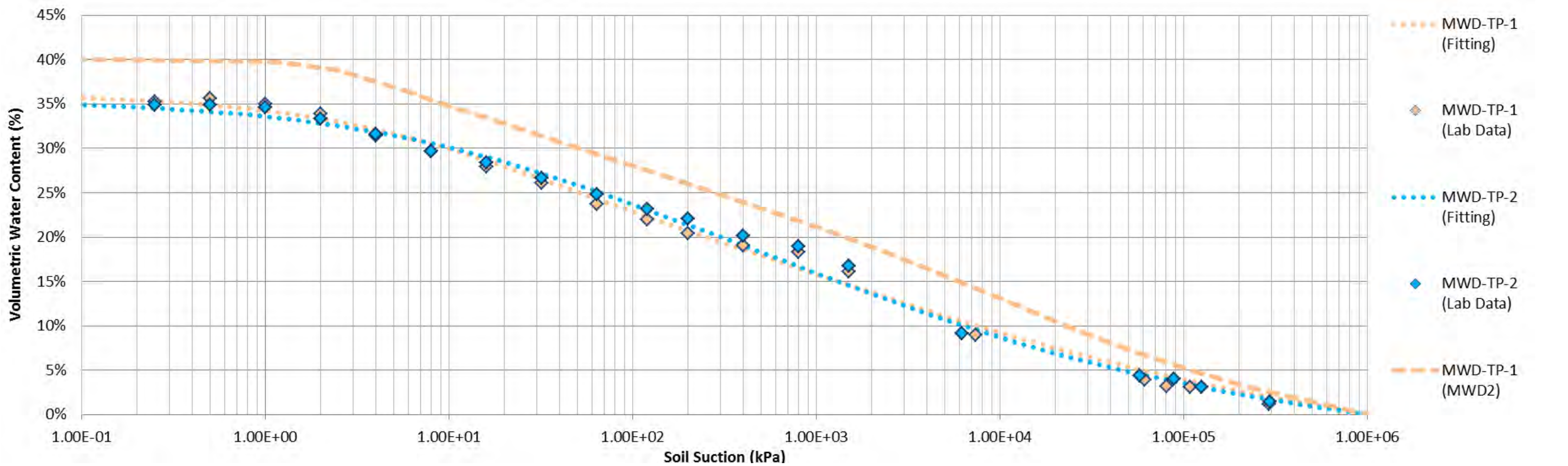

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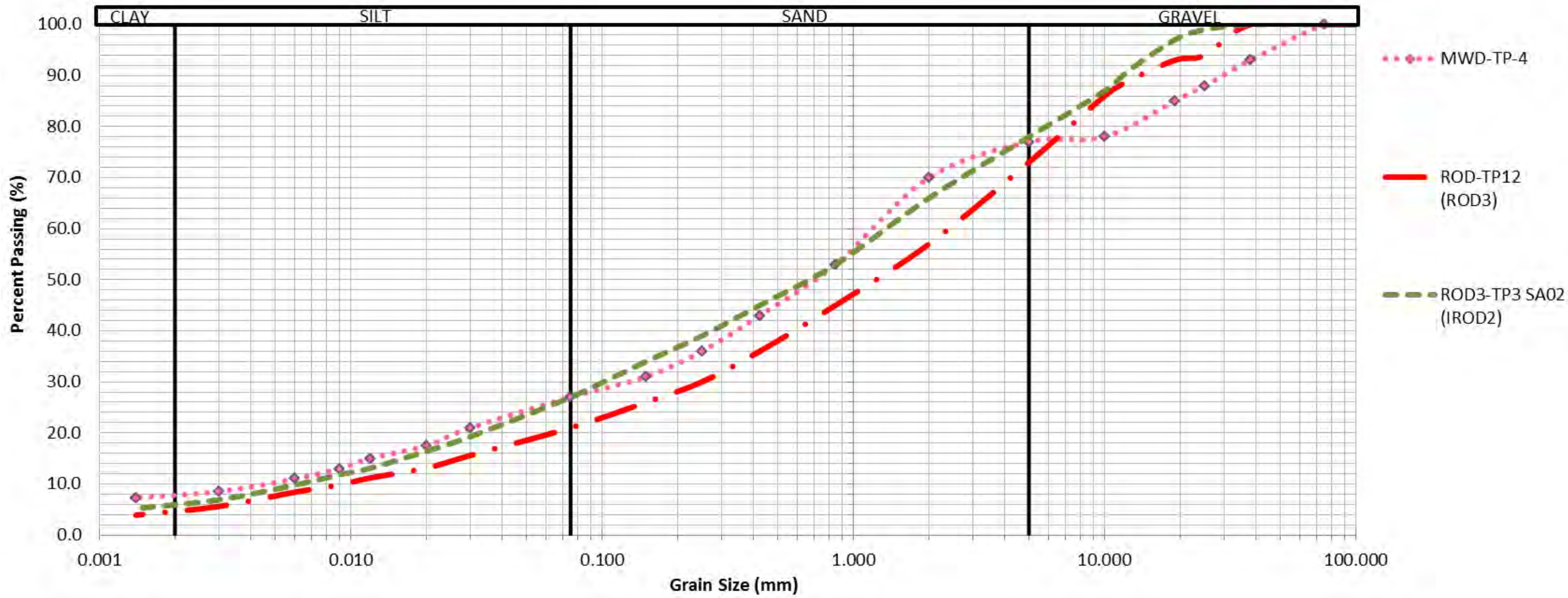
Scoping Level Cover Assessment

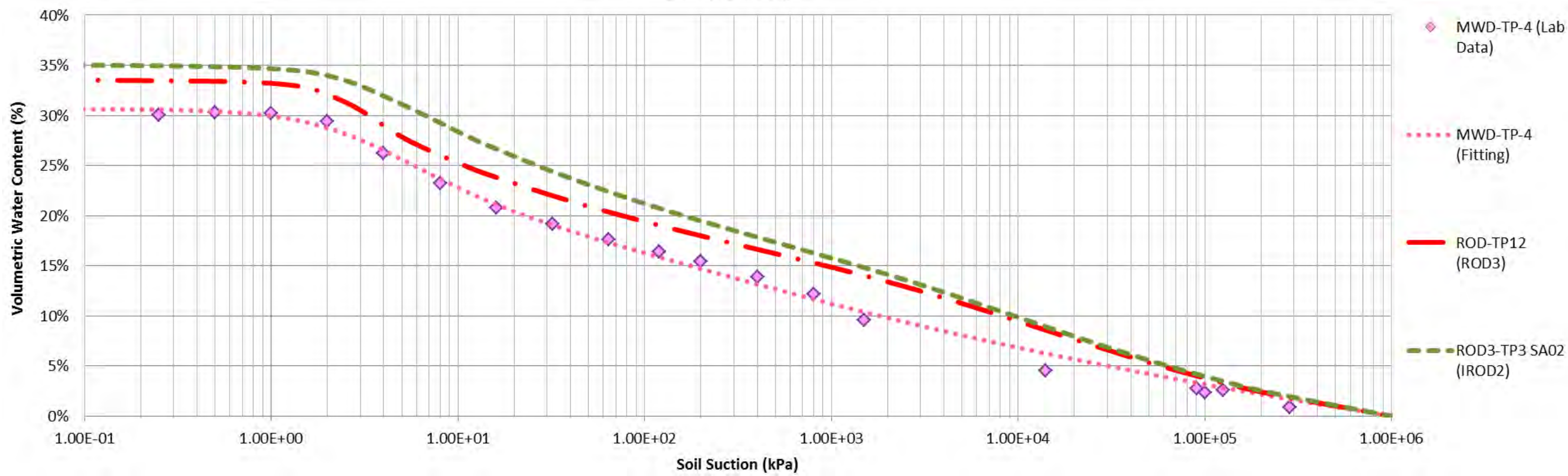
Comparison of Measured and Estimated SWCC's (MWD Material)

Job No: 1CM002.007
Filename: Figure 2-14_1CM002.007_Rev05.pptx

Minto Mine

Date: July 2013
Approved: EMR
Figure: 11





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Scoping Level Cover Assessment

Comparison of Measured and Estimated SWCC's (ROD & IROD Material)

Job No: 1CM002.007
Filename: Figure 2-14_1CM002.007_Rev05.pptx

Minto Mine

Date:	Approved:	Figure:
July 2013	EMR	12

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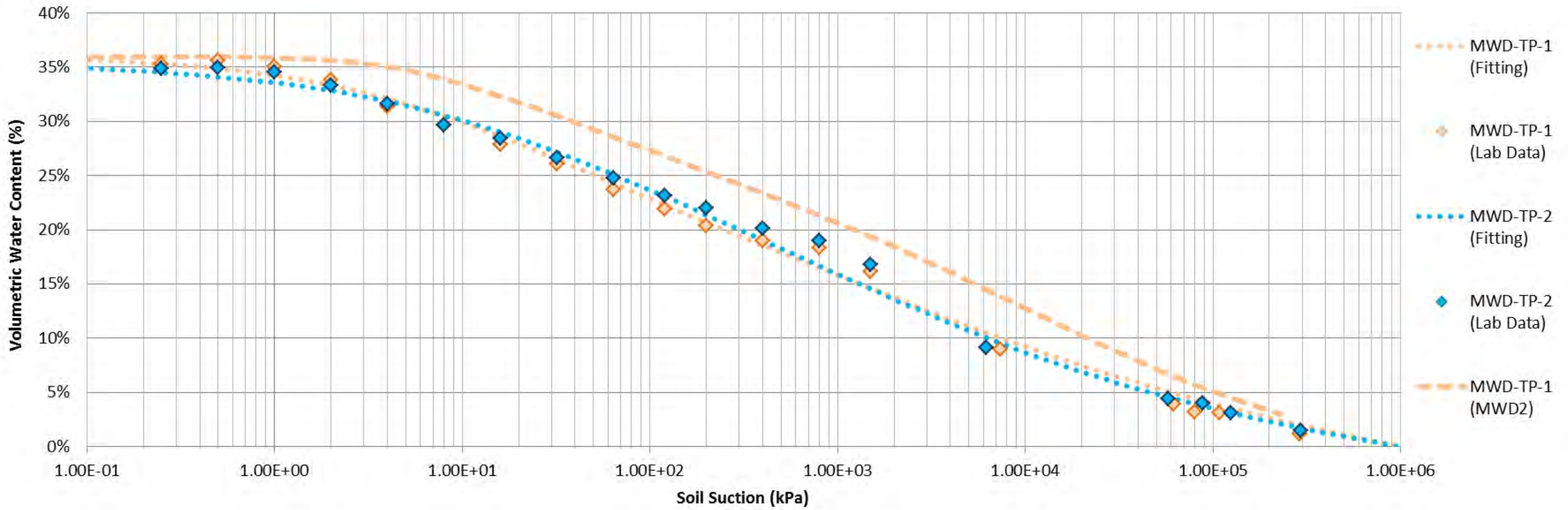

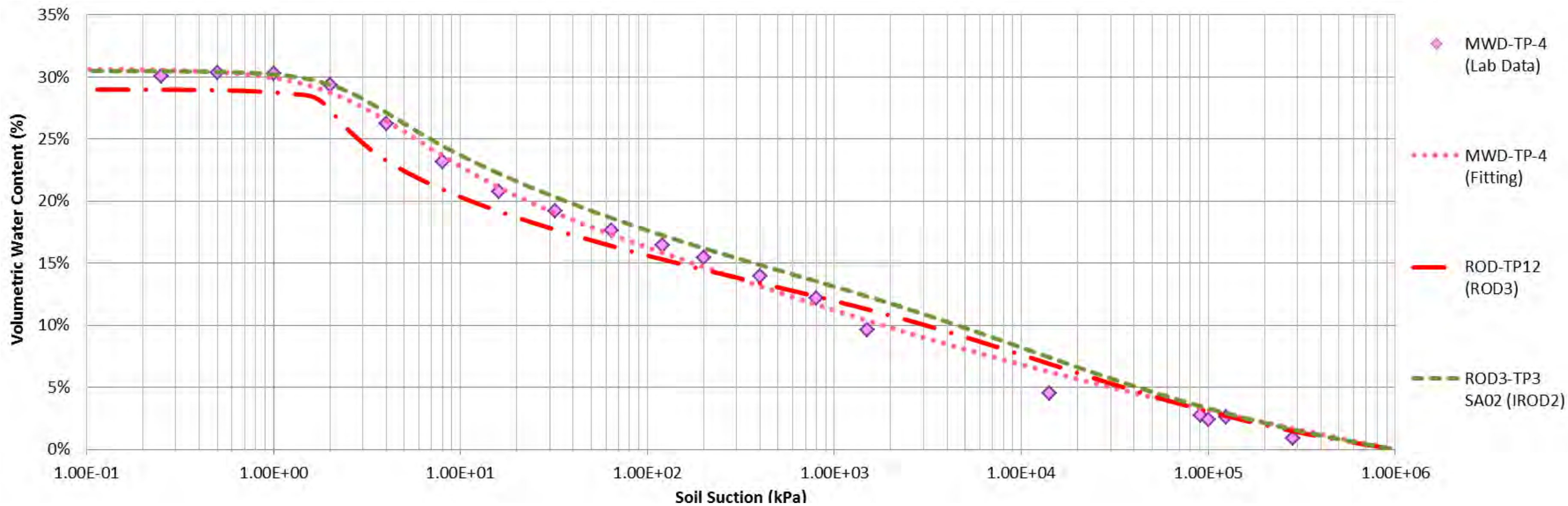

srk consulting	CAPSTONE MINING CORP. MINTO MINE	Scoping Level Cover Assessment
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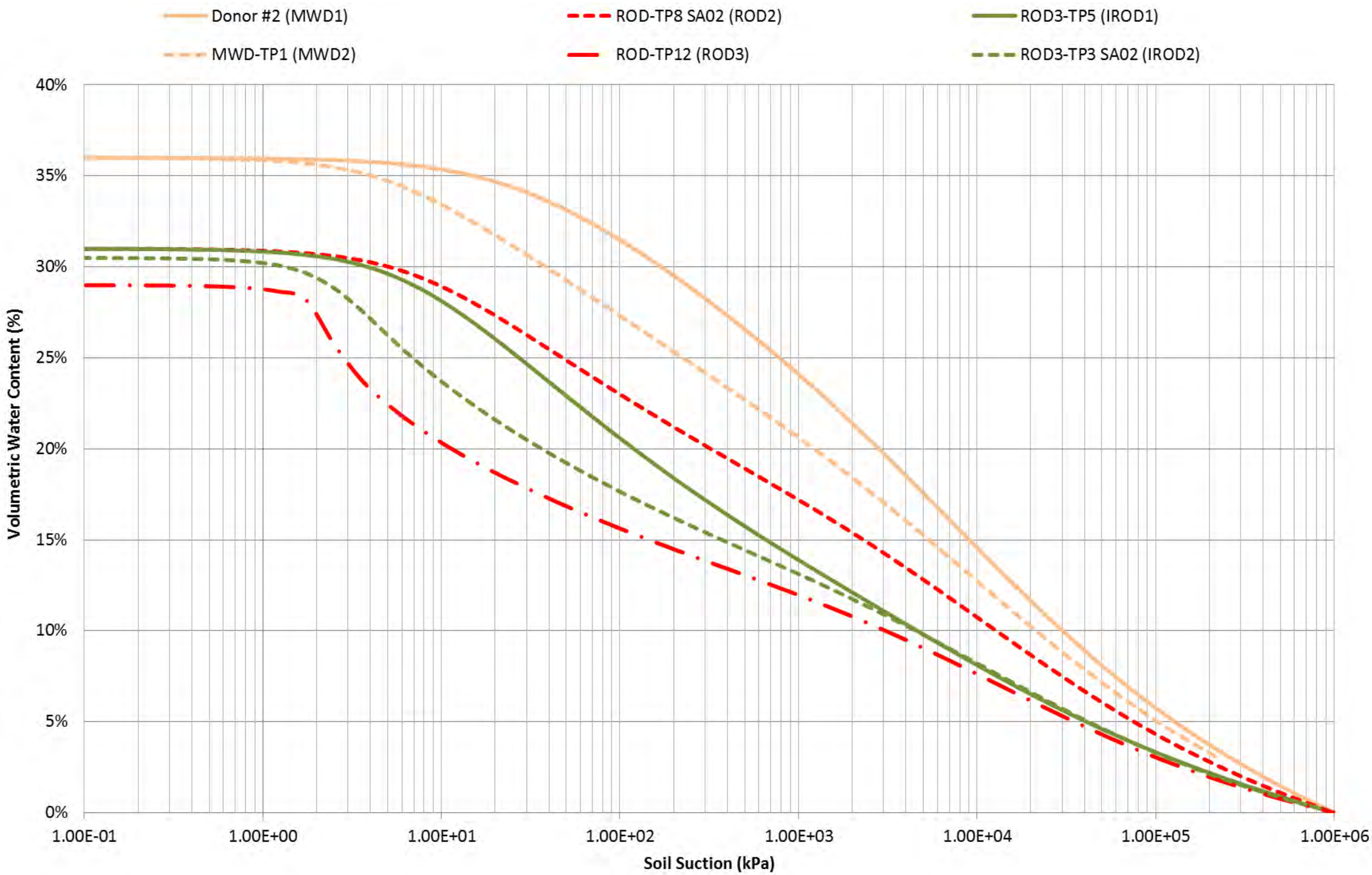
Job No: 1CM002.007 Filename: Figure 2-14_1CM002.007_Rev05.pptx	Minto Mine	Date: July 2013 / Approved: EMR / Figure: 13



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Scoping Level Cover Assessment

Calibrated Soil Water Characteristic Curves

Job No: 1CM002.007

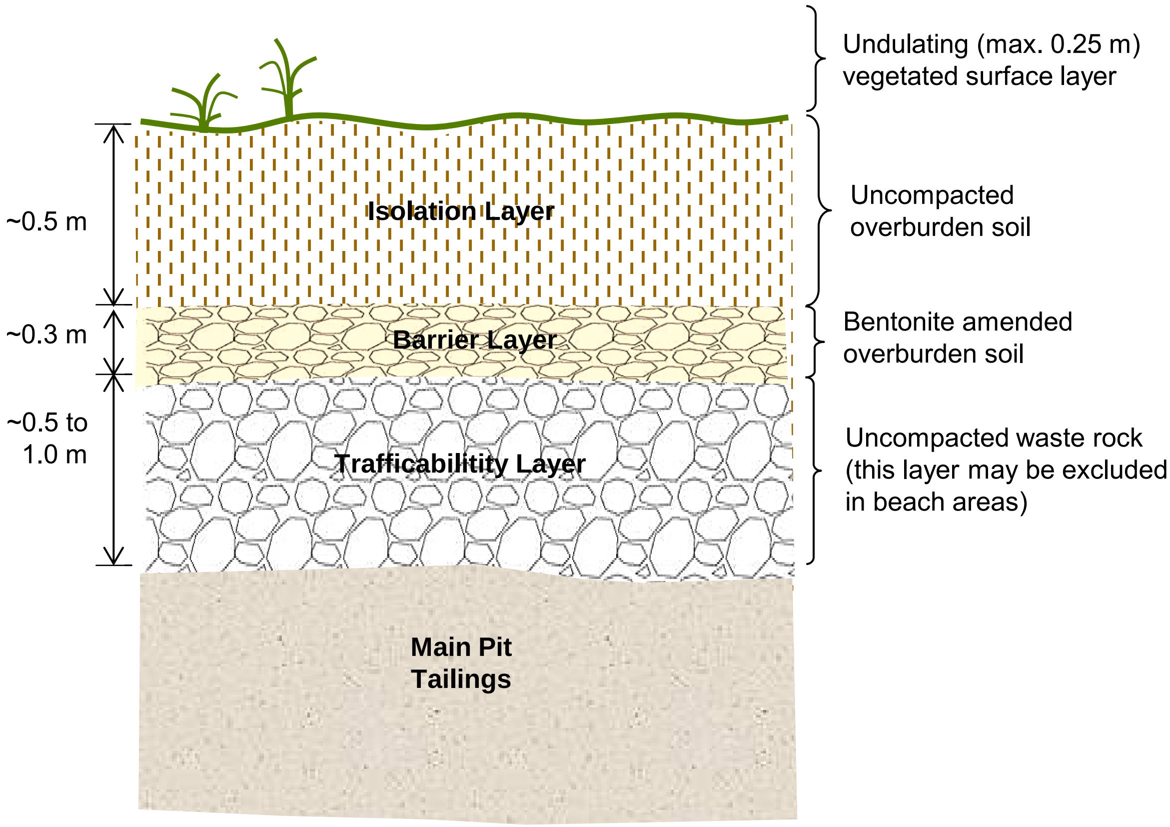
Filename: Figure 2-14_1CM002.007_Rev05.pptx

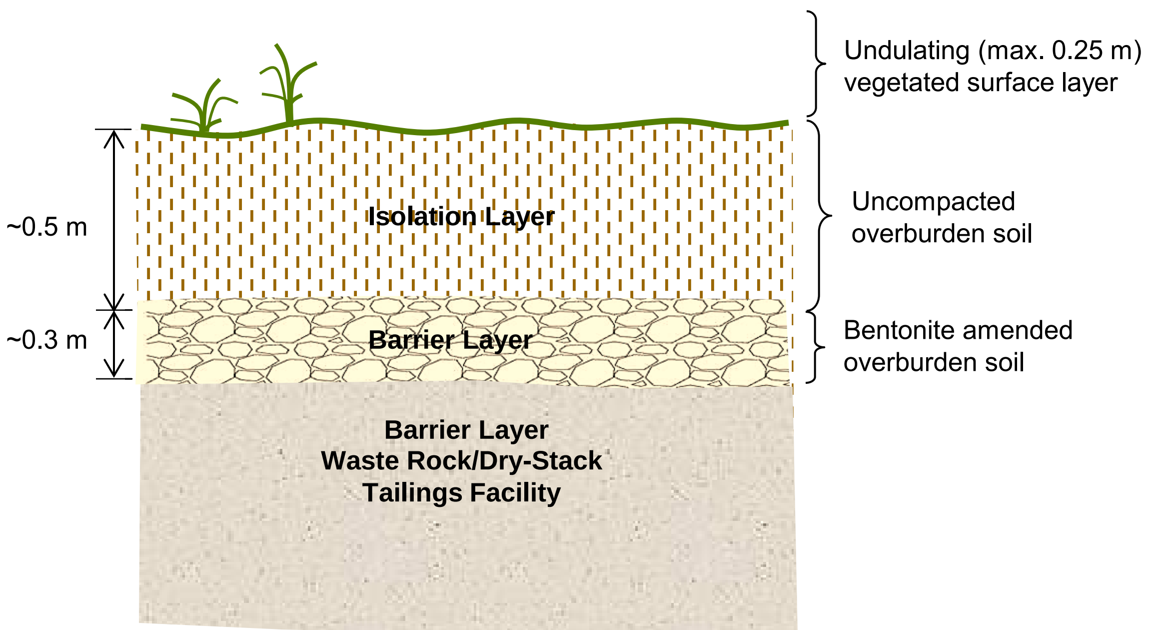
Minto Mine

Date: July 2013

Approved: EMR

Figure: 14





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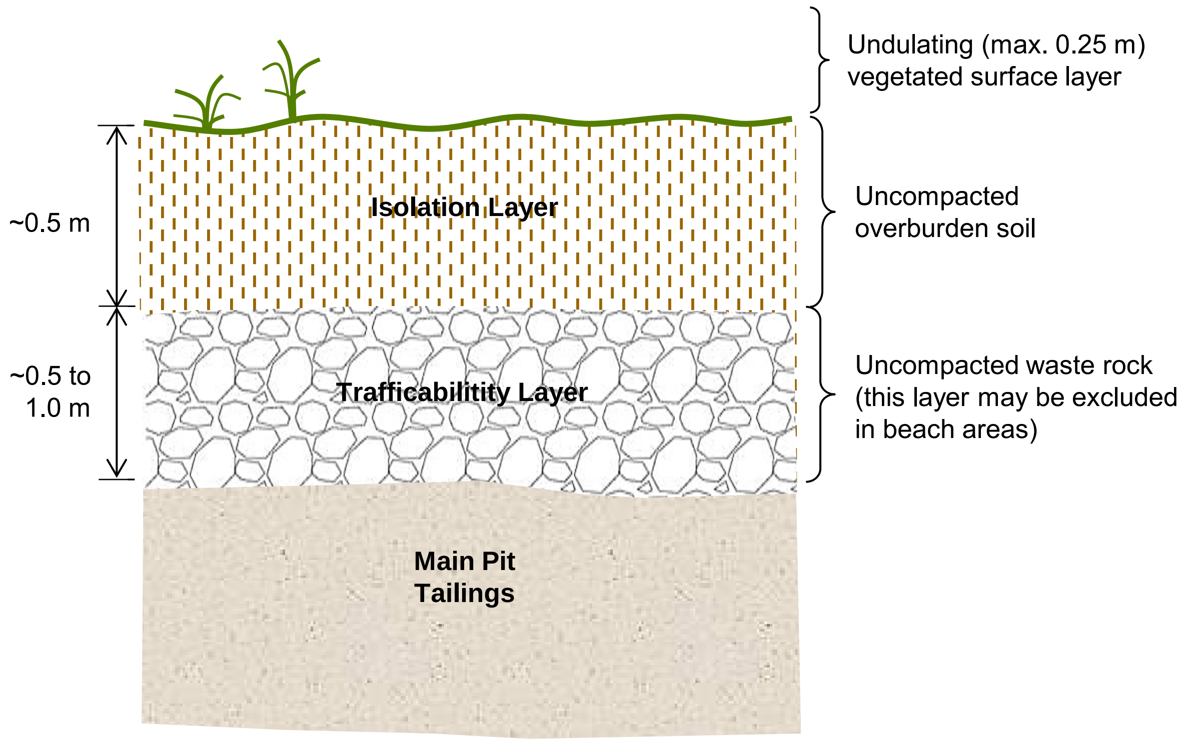
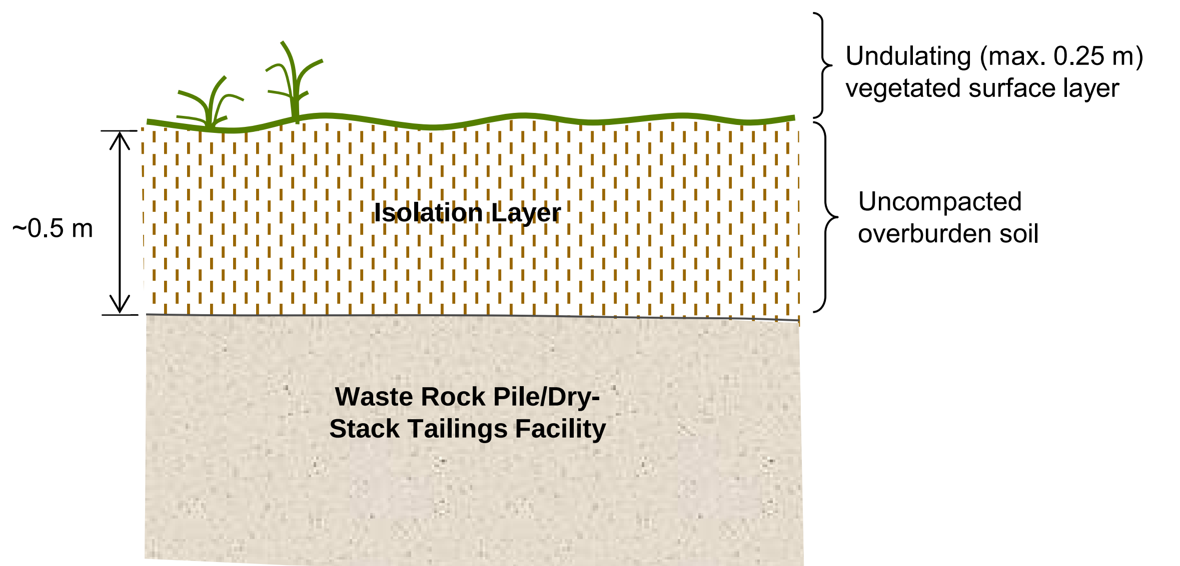
Job No: 1CM002.007 Filename: Figure 15-17_1CM002.0007_Conceptual Covers	Minto Mine	Date: July 2013	Approved: EMR	Figure: **16**





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Scoping Level Cover Assessment

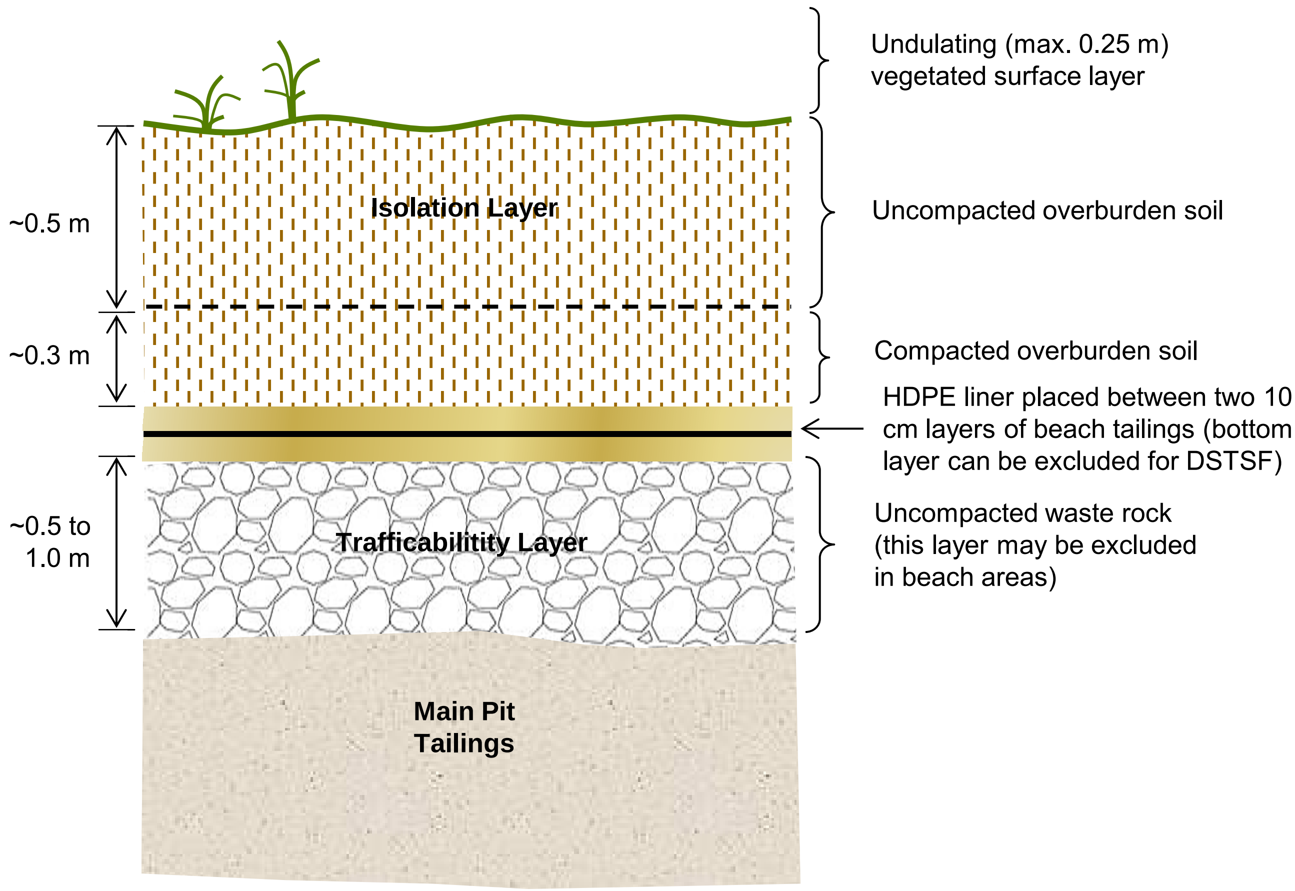
Conceptual Isolation Cover

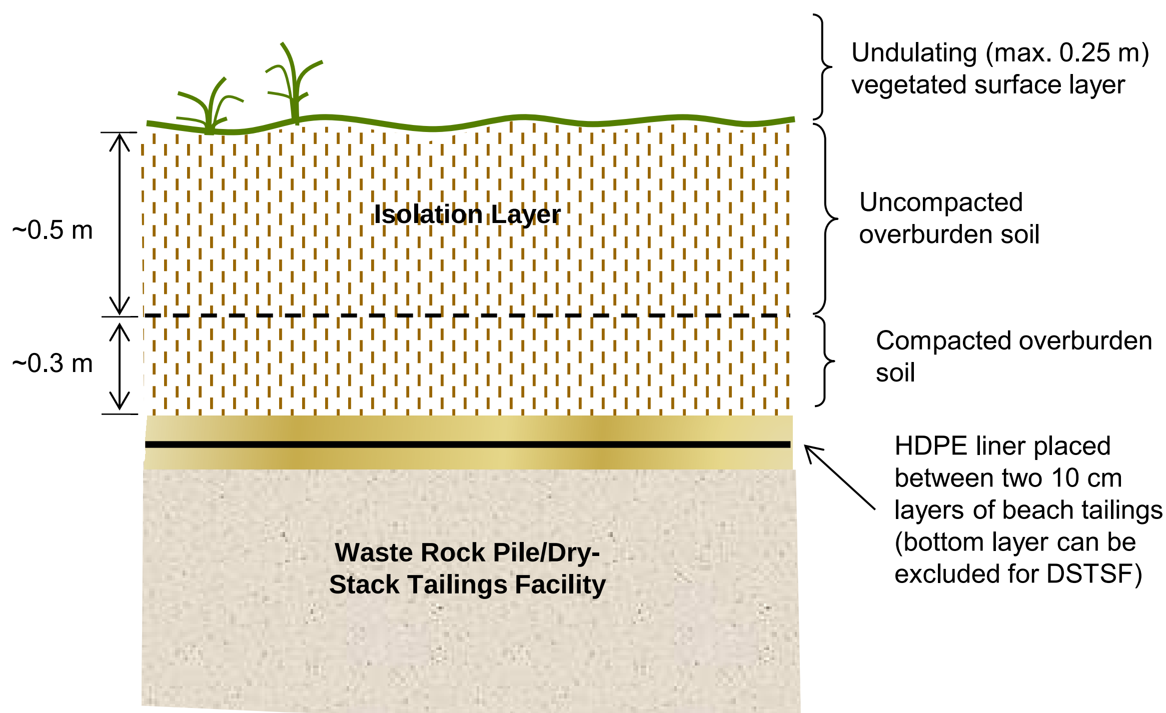
Job No: 1CM002.007

Filename: Figure 15-17_1CM002.0007_Conceptual Covers

Minto Mine

Date:	Approved:	Figure:
July 2013	EMR	15





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MINTO MINE

Scoping Level Cover Assessment

Conceptual Very Low Infiltration Cover

Job No: 1CM002.007

Filename: Figure 15-17_1CM002.0007_Conceptual Covers

Minto Mine

Date: July 2013

Approved: EMR

Figure: 17

Appendix E2
Memo - Minto Mine Closure Covers: Results of Numerical Modelling to Bracket Percolation Predictions

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Memo

To:	Ryan Herbert, Minto Explorations Ltd.	**Client:**	Minto Explorations Ltd
From:	Iozsef Miskolczi, PEng, Maritz Rykaart, PhD, PEng	**Project No:**	1CM002.030
Cc:	Dylan MacGregor, PGeo, SRK	**Date:**	October 14, 2015
Subject:	Minto Mine Closure Covers: Results of Numerical Modelling to Bracket Percolation Predictions		

1 Introduction

1.1 General

Preliminary water quality modelling of seepage from Minto Mine waste facilities, as a result of meteoric percolation through them, suggests that under worst-case load predictions the water quality in Minto Creek will not meet the post-closure objectives. Closure covers that control the percolation rate are one of many possible strategies that are being considered to mitigate this situation.

A Scoping Level Cover Assessment was completed for the Minto mine to evaluate what the most suitable closure cover may be (SRK 2013a) given the site specific climatic conditions and availability of candidate cover materials. The scoping study identified several candidate closure cover designs and the approximate range of net percolation that could be associated with each cover concept. Those percolation ranges were based on engineering judgement derived from knowledge of soil covers as well as soil cover performance at other sites, as opposed to measured or predicted (i.e. modelled) rates.

This memorandum presents the results of surface flux boundary modelling that further defines and brackets the likely range of percolation for the proposed soil covers at Minto Mine. These results supplement the existing database of information and provide greater confidence in the use of closure covers as a mitigation strategy.

1.2 Modelling Approach

For the purpose of this study we have adopted the term percolation, as opposed to infiltration, to define the meteoric water that will migrate through the cover and underlying waste, and emerge as seepage at the toe of the facility or report to groundwater. In order to model percolation, a surface flux boundary model must be used, which accounts for the physical processes (e.g. infiltration, evapotranspiration, and runoff) that take place at the cover surface (i.e. at the interface between the cover and the atmosphere). This type of modelling is complex, requires good quality input data, and ideally, long-term in-situ calibration data.

Since no calibration data is available, the modelling approach was to develop a most realistic base case scenario, and then through sensitivity analysis establish how the modelling results will be impacted as parameters change. This process allows for a rigorous assessment of the parameters that drive the cover performance, such that the expected percolation rates can be determined with a high level of confidence.

In order to do this most efficiently, a pseudo- surface flux boundary model (Hydrus 1D (Šimůnek *et al*. 2009)) was used for the modelling. The base case scenario was subsequently verified using a true surface flux boundary model, SVFlux (SoilVision 2009). A true surface flux boundary model calculates actual evaporation using the Modified Penman equation (Wilson 1990), while in the pseudo surface flux boundary model actual evaporation is estimated based on a user defined potential evaporation. Calculating actual evaporation requires a higher level of complexity (i.e. non-linearity) in the numerical simulation which substantially increases the computing time. It was however demonstrated that with proper verification the approach as adopted (i.e. modelling using Hydrus 1D and verification using SVFlux) is reliable and efficient (Rykaart and Noël 2003).

2 Methods

2.1 Conceptual Model and Model Setup

The objective of the modelling is to bracket the likely range of percolation through various single layer soil covers that could be constructed using the candidate soil material that is readily available at Minto Mine. The model assumes that no water table is present within the waste substrate and that any water that percolates through the cover will continue to drain unimpeded through the underlying waste exiting the model at the bottom. In real life however, at the waste dump scale this drainage water will either emerge as toe seepage or report to groundwater.

This conceptual model is represented in the computer models as a 10 m high, one-dimensional column consisting of two layers: a soil cover (of variable thickness) and underlying waste material (waste rock or tailings) respectively. The top surface is flat, however the simulations do not allow for ponding to develop; this corresponds to the physical equivalent of shedding excess water (if it were to occur) as runoff.

In each case the model is run for a continuous period of 20 years in daily time-steps, using a synthesized climatic dataset. This approach results in 20 different annual percolation rates, representing a range of expected outcomes taking into consideration variability of actual climatic conditions. The synthetic climatic data set does not take into consideration climate change.

2.2 Model Input Data

2.2.1 Meteorological Data

Data Source

Daily precipitation and evaporation data is required for modelling. In order to develop a long-term modelling dataset, daily regional meteorological data was obtained from Environment Canada's Pelly Ranch weather station. The Pelly Ranch data, which dates back to 1955, were subsequently modified to better represent Minto site conditions by applying site specific climate correlation factors that were previously developed based on data from two on-site weather stations (SRK 2012).

Precipitation

The Pelly Ranch meteorological data was parsed for incomplete years and an initial 49-year daily dataset was compiled stretching from 1957 to 2009. This dataset was further purged to remove all years with total precipitation above the 1:50 years wet year (461 mm) and below the 1 in 50 years dry year (218 mm) (SRK 2012). The twenty most recent years from the resulting synthetic dataset were used as model input, from the period between 1986 and 2009, with the years 1992, 1996, 1998 and 2008 excluded. A summary of this annualized dataset is presented in Table 1.

Table 1: Yearly Total Precipitation Data for 20-Year Modelling Period

Model Year	Calendar Year	Yearly Total Precipitation (mm)
1	1986	316
2	1987	362
3	1988	301
4	1989	254
5	1990	372
6	1991	362
7	1993	335
8	1994	293
9	1995	307
10	1997	425
11	1999	417
12	2000	453
13	2001	326
14	2002	335
15	2003	330
16	2004	422
17	2005	367
18	2006	261
19	2007	349
20	2009	349

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.030_Closure_Cover_Modelling\!080_Deliverables\Cover Model Results\020_Tables\[Minto_WeatherInput_1CM002.030_Rev01_IM.xlsx]Precip

To study the effect of higher or lower than average precipitation, two subsets of precipitation data, each 5 years long were compiled. The wetter than average dataset is comprising of years exceeding the 1:5 years wet annual precipitation of 380 mm (SRK 2012), as presented in Table 2. The drier than average dataset includes years in which total precipitation was below 275 mm, or 1:5 years dry (SRK 2012) as shown in Table 3.

Table 2: Wetter Than Average Precipitation Years

Model Year	Calendar Year	Yearly Total Precipitation (mm)
1	1964	388
2	1967	408
3	1981	380
4	1985	382
5	2000	453

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.030_Closure_Cover_Modelling\!080_Deliverables\Cover Model Results\020_Tables\[Minto_WeatherInput_1CM002.030_Rev01_IM.xlsx]Precip

Table 3: Dryer Than Average Precipitation Years

Model Year	Calendar Year	Yearly Total Precipitation (mm)
1	1969	260
2	1971	269
3	1975	270
4	1980	257
5	2006	261

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.030_Closure_Cover_Modelling\!080_Deliverables\Cover Model Results\020_Tables\[Minto_WeatherInput_1CM002.030_Rev01_IM.xlsx]Precip

Evaporation

Potential evaporation (PE) was estimated at about 400 mm/year by scaling the lake evaporation data from Pelly Ranch to match the Minto Mine site conditions (SRK 2013a). The monthly total values of PE, shown in Table 4, were obtained by scaling monthly PE values calculated using the Penman-Monteith method (FAO 1998) to match the yearly total of 400 mm.

Table 4: Monthly Distribution of Potential Evaporation

Month	Monthly PE (mm)	Days per Month	Daily PE (mm/day)
Jan	0	31	0.00
Feb	0	28.25	0.00
Mar	0	31	0.00
Apr	0	30	0.00
May	85	31	2.75
Jun	98	30	3.28
Jul	92	31	2.96
Aug	82	31	2.63
Sep	38	30	1.28
Oct	5	31	0.16
Nov	0	30	0.00
Dec	0	31	0.00

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.030_Closure_Cover_Modelling\!080_Deliverables\Cover Model Results\020_Tables\[Minto_WeatherInput_1CM002.030_Rev01_IM.xlsx]Potential Evap

Evapotranspiration

Bare ground evaporation accounts for the water loss at the soil-atmosphere boundary, i.e. the soil surface. Plant transpiration on the other hand is responsible for removal of water from the near-surface of the soil to the full depth of the rooting zone. During the growth season plant transpiration and bare ground evaporation occur simultaneously and the coupled water loss is termed evapotranspiration (Hillel 1980). Bare ground evaporation can however occur outside of the growth season, as long as water at the soil surface is available in liquid form.

The site experiences a short growth season. Based on temperature records from the Pelly Ranch station the average growth season over the most recent 17 years (1998 to 2014) is between May 5 and September 8 (Access 2014). The beginning of the season was considered the fifth consecutive day with mean air temperature above +5°C whereas the end was the first day with killing frost (below -2.2°C). Potential bare ground evaporation (PE) however, which is based on the energy balance governed by the local climate, has a wider range extending between May 1 and October 31. The model assumes that evapotranspiration is possible within this period only, whereas it is considered to be zero between November 1 and April 30.

Snowmelt and Sublimation

To recognize the effect of freezing conditions during winter, snow precipitation was retained and accumulated between October 1 and April 17 annually as snow water equivalent (SWE). Snowmelt was assumed to start on April 17 with freshet lasting two weeks from April 17 to April 30. The entire accumulated SWE was then released as equal daily amounts of meltwater over these two weeks, in addition to any observed precipitation. The ground was assumed to be fully thawed during this period; this is conservative, as in reality thawing would only be starting at this time.

Snow sublimation in the Yukon can lead to considerable snow cover loss. A rigorous study of sublimation performed at a research station near Whitehorse (Pomeroy *et al.* 1999) observed sublimation ranging between 28 and 45 mm per season. Since winter climate conditions influencing the magnitude of sublimation are comparable between Minto and the study site, it was considered that 45 mm of sublimation are representative of Minto site conditions. For modelling purposes, the April 17 SWE was reduced by 45 mm as an allowance for sublimation.

2.2.2 Material Properties

Field investigations completed in 2012 characterized all candidate cover material sources. Tailings samples were obtained from the Dry Stack Tailings Storage Facility and analysed as part of a field investigation conducted in 2013 (SRK 2013b). Particle size distribution (PSD) curves encompassing the full range of candidate cover materials on site are reproduced in Figure 1. Advanced hydraulic testing, including Soil Water Characteristic Curves (SWCC), was performed on representative samples.

Table 3 shows a summary of the candidate cover material properties used in the Hydrus 1D model, while Figure 2 and Figure 3 present the PSD and SWCC curves used in modelling.

A literature search was performed to gather properties for the waste rock to be used in modelling. The material considered to be most appropriate for representing the Minto waste rock was a waste rock sample from Greens Creek mine (Hopp *et al.* 2011) due to the igneous (hard rock) nature of both the Greens Creek and Minto geology. For the sensitivity analysis, finer waste rock properties were used from SRK's database, while the coarser waste rock was simulated using van Genuchten curve fitting parameters (van Genuchten 1980). The water retention properties for tailings were predicted using the Rosetta model (Schaap *et al*. 2001), based on a Minto sample PSD with a bulk density of 1.9 T/m^3. No SWCC curves are available for the tailings and coarse waste rock materials, and therefore modelling was done using the unsaturated curve fitting parameters listed in Table 5.

Table 5: Summary of Material Properties Used in Modelling

Materials ID	Material Type	θr	θs	α (1/m)	n	K_{sat} (m/day)	l
MWDTP4 [a]	Cover	0	0.303	2.67	1.20	0.164	0.5
MWDTP2 [a]	Cover	0	0.360	1.09	1.19	0.025	0.5
MWDTP3 [a]	Cover	0	0.238	5.50	1.22	3.715	0.5
Greens Creek WR [b]	Waste Rock	0.012	0.410	5.43	2.03	1.728	0.5
Finer WR [c]	Waste Rock	0	0.361	32.65	1.22	4.790	0.5
Coarser WR [d]	Waste Rock	0.020	0.450	2.00	2.50	5.000	0.5
Tailings [e]	Tailings	0.027	0.272	6.31	1.22	0.081	0.5

Source: \\VAN-SVR0\Projects\01_SITES\Minto\1CM002.030_Closure_Cover_Modelling\Task_300-CoverModel\Hydrus1D\Minto_CoverHydrusModel_Summary_Rev06_KK_IM.xlsx

Notes:

[a] : Based on RETC model using van Genuchten – Mualem method; K_sat based on laboratory result.
[b] : Hopp, L. et al. 2011.
[c] : Based on RETC model using van Genuchten – Mualem method; K_sat based on laboratory result.
[d] : Theoretical van Genuchten curve fitting values representative of a generic waste rock.
[e] : Estimated values based on particle size distribution and density of tailings on site.

2.2.3 Boundary Conditions

The top boundary condition of the one-dimensional column is a time-dependent (daily time step) atmospheric boundary (precipitation and evaporation). The bottom boundary condition is a unit gradient to simulate unsaturated gravitational flow exiting the model. Being a one-dimensional model, there are no side boundaries.

2.2.4 Initial Conditions

Initial conditions were expressed in terms of gravimetric moisture content, set at 7% for waste rock, 18% for tailings, and 11% for the soil cover materials, respectively. These moisture contents represent the field moisture content of the soil samples collected during the field programs in 2012 (SRK 2013c) and 2013 (SRK 2013b), representing reasonable initial conditions for the model.

2.2.5 Vegetation

Vegetation on site is dominated by mixed Trembling Aspen and Lodgepole Pine forests at various stages of succession following the relatively frequent forest fires. Willow species dominate the shrub covered area, while being ubiquitous in the understory of the forested areas (Access 2013).

No specific information of actual plant transpiration rates was available for model calibration. Therefore the model made use of a conservative pasture-type vegetation, which is one of the Hydrus 1D built-in vegetation functions. A constant rooting depth of 10 cm was applied.

2.3 Scenarios Evaluated

2.3.1 Base Case Scenario

The base case scenario assumes a simple 0.5 m thick soil cover overlying waste rock. The cover material is represented by test data from sample MWDTP4 (SRK 2013c) and the waste rock is represented by the Greens Creek sample. The surface is assumed to have no vegetation. Normal precipitation is applied as a 20-year long daily sequence, with snow precipitation retained during the winter months (simulating snow accumulation on frozen ground), before being reduced by an amount of 45 mm per year to account for sublimation losses. The remaining snow water equivalent is subsequently release to simulate a freshet lasting 14 days starting April 17 each year. PE equal to 400 mm annually is distributed monthly in equal daily increments (see Table 2).

The base case scenario was simulated using both Hydrus and SVFlux. Since SVFlux is a more rigorous model, it allows for a confirmation on whether the Hydrus model result is reasonable.

2.3.2 Sensitivity Analysis Scenarios

The objective of the sensitivity analysis was to evaluate which parameters have the largest influence on the percolation predictions. To that end the following sensitivity runs were completed:

- A delayed freshet (starting two weeks later, on May 1);
- Finer and coarser cover material;
- Finer and coarser underlying waste rock material;
- No sublimation and increased sublimation;
- Increased cover thickness;
- Upset climatic condition; and
- Presence of vegetation.

In addition, to allow for benchmarking of the results, simulations were also completed with no cover. Finally, simulations were completed to determine the percolation rates through these covers if they were placed over tailings.

3 Modelling Results and Discussion

3.1 Results Summary

Table 6 presents a summary of the complete results for all runs, including the sensitivity analyses. Figure 4 presents the results as a chart showing the range of yearly net percolation as percent of total precipitation for that year. The boxed number represents the arithmetic average of the yearly net percolations over the 20-year simulation, and as such does not represent any particular modelled year.

Table 6: Summary of Modelling Results

Case #	Scenario	Net Percolation (% Annual Precip.)			Total Precip. (mm)	Total Net Perc. (mm)	Total Evap. (mm)	Total Run-off (mm)
		Max.	Min.	Avg.				
1	Base Case	43%	6%	23%	6,038	1,429	4,629	0
2	Late Freshet (May 1)	35%	<1%	14%	6,038	934	5,126	0
3	Finer Cover Material	40%	2%	21%	6,038	1,305	4,717	0
4	Coarser Cover Material	44%	5%	23%	6,038	1,447	4,673	0
5	Finer Waste Rock	46%	9%	23%	6,038	1,428	4,626	0
6	Coarser Waste Rock	49%	8%	28%	6,038	1,749	4,316	0
7	1 in 5 years wet	29%	17%	23%	7,065	1,612	5,468	0
8	1 in 5 years dry	26%	8%	14%	4,607	682	3,949	0
9	Thicker Cover (1 m)	38%	3%	19%	6,038	1,179	4,824	0
10	Thicker Cover (2 m)	36%	3%	18%	6,038	1,134	4,904	0
11	Tailings WR traffic layer under cover	38%	6%	21%	6,038	1,299	4,750	0
12	WR only; No Cover	65%	34%	45%	6,038	2,742	3,291	0
13	Tailings with WR; No Cover	61%	31%	41%	6,038	2,500	3,541	0.3
14	Tailings only; No Cover	60%	26%	39%	6,038	2,383	3,665	0
15	BaseCase; No Sublimation	54%	13%	33%	6,933	2,323	4,651	0
16	Vegetation	40%	4%	21%	6,038	1,298	4,719	0
17	Base case (80 mm sublimation)	30%	1%	14%	5,332	759	4,579	0
18	SV Flux check	44%	5%	19%	6,044	1,228	4,821	0
19	SV Flux check; No Sublimation	54%	11%	29%	6,940	2,090	4,851	0

Source: \\van-svr0\Projects\01_SITES\Minto\1CM002.030_Closure_Cover_Modelling\!080_Deliverables\Cover Model Results\020_Tables\[Minto_CoverHydrus Model_Summary_Rev13_IM.xlsx]Summary

In all cases the results are predicted as a range around an average value as opposed to a single percolation value. This is intentional, as surface flux boundary modelling cannot yield absolute results. The percolation outcome is a function of the complex interaction between antecedent meteoric events and pre-existing soil moisture conditions, which naturally is highly variable. Similar precipitation events can yield vastly different percolation results depending on preceding soil moisture conditions. Therefore the appropriate use of modelling is to bracket the likely range of results, taking into consideration those elements that drive the outcome.

Another way to look at the results is to consider the normal distribution of the range. For example, Figure 5 presents the 20 years of precipitation data, indicating the variability which ultimately resulted in the Base Case model calculating a range of percolation between 6% and 43% with the average of 23%.

Arranging the predicted range into a histogram (Figure 6) reveals that eight out of 20 years the percolation is likely to be in the near-average range, followed by six out of twenty years moderately exceeding the average. This compares to total precipitation of about 300 and 350 mm respectively, thus representing a rough correlation between the precipitation and net percolation. The correlation however is reliable only for the modelled results and extrapolation outside of the modelled range may not be valid. This is due to the fact that the relationship between precipitation and percolation is not linear, as described earlier in this section.

Using some basic statistical tools, the same Base Case results can be arranged into a normal probability distribution, as shown in Figure 7. This graphic shows that, for example, 90% of the time percolation will be less than 35% of the yearly precipitation; conversely one in ten years can be expected to have net percolation higher than 35%.

3.2 Model Verification

The Base Case (Case #1) model, which uses the Hydrus 1D code yields an average percolation of 23%, with an overall range between 6 and 43%. The equivalent scenario, using the more rigorous SVFlux code (Case #18), yields and average percolation of 19%, with an overall range of 5 to 44%. A second verification check was made for Case #15 which is the Base Case model, but without sublimation. In this case the average percolation is 33%, while for Case #19 (the equivalent SVFlux run) it is 29%. For Case #15 the overall percolation range is between 13 and 54%, while for Case #19 it is between 11 and 54%.

In all instances the overall range of percolation results are near identical, and most certainly within the accuracy range of surface flux boundary modelling. The average percolation is consistently 4% lower for the SVFlux model runs. This difference is ascribed to the fact that for the SVFlux model runs the evaporation is slightly higher resulting in lower percolation. As described earlier, SVFlux is a true surface flux boundary model that calculates actual evaporation for each time step using the Modified Penman equation, and as a result, this higher evaporation is expected. The small difference of 4% is however within the level of accuracy of this type of modelling, and therefore the Hydrus 1D modelling is entirely suitable. The fact that the Hydrus 1D model reports a slightly higher percolation rate suggests a level of conservatism which is entirely appropriate.

3.3 Base Case (0.5 m Soil Cover over Waste Rock)

A 0.5 m soil cover over waste rock reduces percolation by almost half to 23%, and similarly the range drops to between 6 and 43%. This demonstrates that even a nominal soil cover results in a considerable reduction in percolation, and therefore is potentially beneficial as a mitigation strategy.

3.4 Uncovered Waste Rock and Tailings

The average percolation for the uncovered waste rock (Case #12) and tailings (Case #14) are 45 and 39% respectively. The range for uncovered waste rock is 34 to 65%, while for the uncovered tailings its 26 to 60%. Tailings percolation is less due to the finer grained nature of the material, which retains more moisture near surface making some of that moisture subsequently available for evaporation.

3.5 Simple Soil Cover Over Tailings

Although it would be possible to apply a simple 0.5 m thick soil cover over the Minto Dry-Stack Tailings Facility, this would not be possible or practical for hydraulically placed tailings in the Main Pit. To ensure trafficability, a 1 m thick layer of waste rock would likely first be required. The effect that has on the modelled percolation rate is illustrated by Case #13, which increases the average percolation to 41% compared to 39% for the uncovered tailings. In both these cases the overall percolation range is similar as illustrated in Figure 4. This result is plausible, as the waste rock is coarser than the tailings allowing for higher infiltration and less evaporation; however, with the finer tailings only 1 m below the surface, some moisture remains more available during wetter periods, which means the average percolation is slightly less than the uncovered waste rock.

Covering the trafficking layer with a 0.5 m simple soil cover (Case #11) has the net effect of reducing the average percolation to 21% and the range to between 6 and 38% which is similar to the performance of the Base Case (Case #1).

3.6 Effect of Cover Material Composition

As illustrated in Section 2.2.2, the available candidate cover materials have a significant range in material properties. Modelling the finer and coarser ends of the spectrum (Case #3 and #4 respectively) suggest that this variability does not materially influence the outcome, since the variability in average percolation between the three cover materials is only 2%. This confirms that for the materials characterized to date there is no preferred material type with which lower percolating covers can be constructed.

3.7 Effect of Cover Thickness

Increasing the cover thickness from 0.5 m to 1 m (Case #9) has the effect of reducing net percolation by about 4%, and the overall range in percolation becomes slightly smaller. Further increasing the cover thickness to 2 m (Case #10) results in a negligible additional improvement, which is arguably less than the model accuracy. This outcome is consistent with the cover material properties, in that the capillarity of the cover material is around 1 m, which means that moisture that passes beyond this limit is unlikely to be released via evaporation.

3.8 Effect of Waste Rock Material Composition

Model simulations with a finer (Case #5) and a coarser (Case #6) waste rock material demonstrate a reasonable sensitivity when measured against the Base Case cover. For the finer waste rock there is no effect on the average percolation rate; however, the range shifts towards the higher end as illustrated in Figure 4. When modelling a coarser waste rock, the average net percolation increases to 28%, and the overall range shifts up (similar to the finer waste rock) to between 12 and 49%. This result is consistent with the observations in Section 3.7 above, suggesting that a cover thickness of 0.5 m is thin enough that it is influenced by the underlying material type. Therefore, with only 0.5 m of cover, having a coarser waste rock with less water retention capability will result in less evaporation and thus greater percolation.

3.9 Effect of Freshet Timing

Delaying the freshet by two weeks (Case #2) has a significant effect on the model outcome. This yields an average percolation of 14% with the range from less than 1 to 35%. The reason for this dramatic reduction is the fact that the model allows for evaporation starting on May 1, and therefore some of the freshet water can evaporate, rather than being allowed to simply percolate through the cover.

3.10 Effect of Sublimation

The model outcome is very sensitive towards the sublimation assumptions. Not allowing for any sublimation (Case #15) results in an increase in average percolation of 10% to 33%, while increasing the sublimation from 45 mm per year to 80 mm per year (Case #16) reduces the average net percolation from 23% to 14%. This result makes sense, as by increasing or decreasing the sublimation, the amount of water that is released during the freshet is increased or decreased, with freshet being a major contributor towards percolation in the Minto environment.

3.11 Effect of Wetter or Dryer Than Normal Climatic Years

To study the effect of abnormally dry or wet precipitation, synthetic subsets of five years were assembled, as described in Section 2.2.1. The models were run for 20 years, using the same 1,825-day weather record four times back-to-back. As expected, the dryer climate (Case #8) resulted in a significant reduction of the average percolation, to about 14%, with the range also shifting downward, to range between 8 and 26%.

The average percolation for the wetter climate (Case #7) remained unchanged compared to the base case, with the increase of the minimum percolation to 14% as expected. The decrease of the maximum percolation to 29% is however counter-intuitive, and is explained by the fact that although total yearly precipitation is higher in each of these years, there are fewer distinct high precipitation events driving massive percolation breakthrough.

3.12 Effect of Vegetation

The model indicates that grassy vegetation (pasture) established on the cover (Case #17) has a small effect on improving the cover performance. This result is perhaps less pronounced than general experience with vegetated covers would suggest. Evapotranspiration in cold climates is a complex process, and in the absence of site specific calibration data the modelled result remains indicative that any vegetation would modestly increase the cover performance.

4 Conclusions

The modelling results in this memo demonstrate that simple soils covers, using locally available materials can be effectively used to reduce percolation through the waste products (waste rock and tailings) by up to 50% compared to the uncovered waste. Uncovered, the waste rock and tailings percolation is about 39 and 45% respectively, while with a simple 0.5 m thick soil cover these average percolation rates decrease to about 23%. With some refinement, such as increasing the cover thickness to about 1 m and by adding some vegetation, the average percolation could likely be reduced to around 20% or less.

The sensitivity analysis shows that the outcome is most sensitive to climatic inputs (such as the timing of freshet and the rate of sublimation) as opposed to material properties, whether waste rock or cover soils. Since these climatic variables cannot be managed through engineering solutions, relying on the cover performance improvements suggested by these model outcomes would not be prudent.

It is important to note that in all cases, the overall range of percolation needs to be considered, as opposed to a single average value. Any water quality assessment should take into consideration the range of cover performance indicated by the modelling results as summarized in Figure 7.

Although the modelling presented has been verified by using a rigorous true surface flux boundary code, it remains uncalibrated and therefore the built-in conservatism is appropriate. One important example of this is evident in how the model is simulating runoff. The model results indicate that virtually no surface run-off will occur; however, there is clear evidence that in reality, runoff does occur at the site. Should covers be deemed an appropriate mitigation strategy, more rigorous refinement of the modelling should be considered at the more advanced design stages, including assessing 2-D effects of slopes to better reflect runoff and incorporation of the influence of frozen covers on freshet percolation. Notwithstanding the limitations mentioned in this document, the results as presented are deemed indicative of the most reasonable upper bound of expected percolation.

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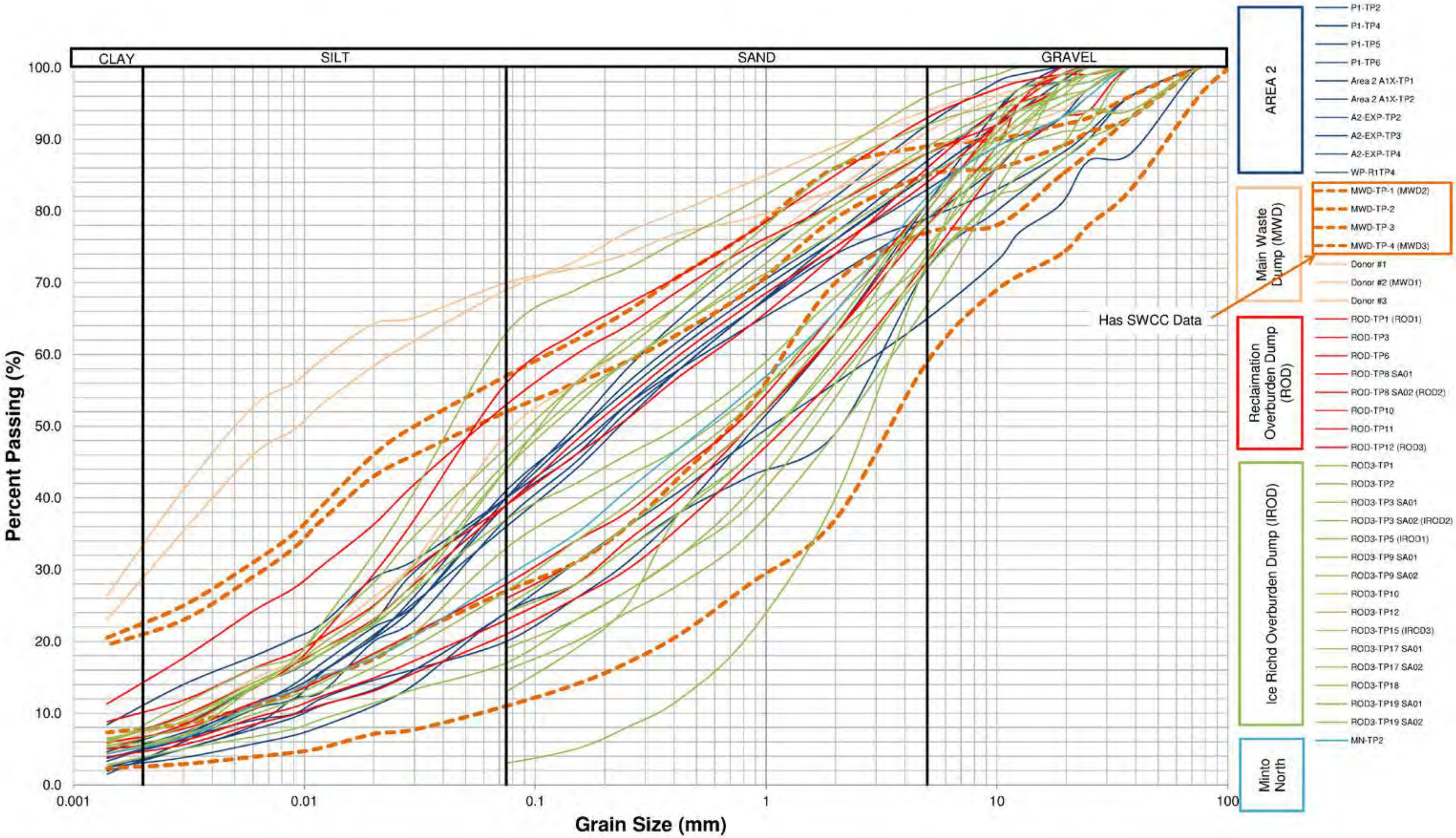
Figures



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Closure Covers Model

Particle Size Distribution of all Candidate Cover Material on Site

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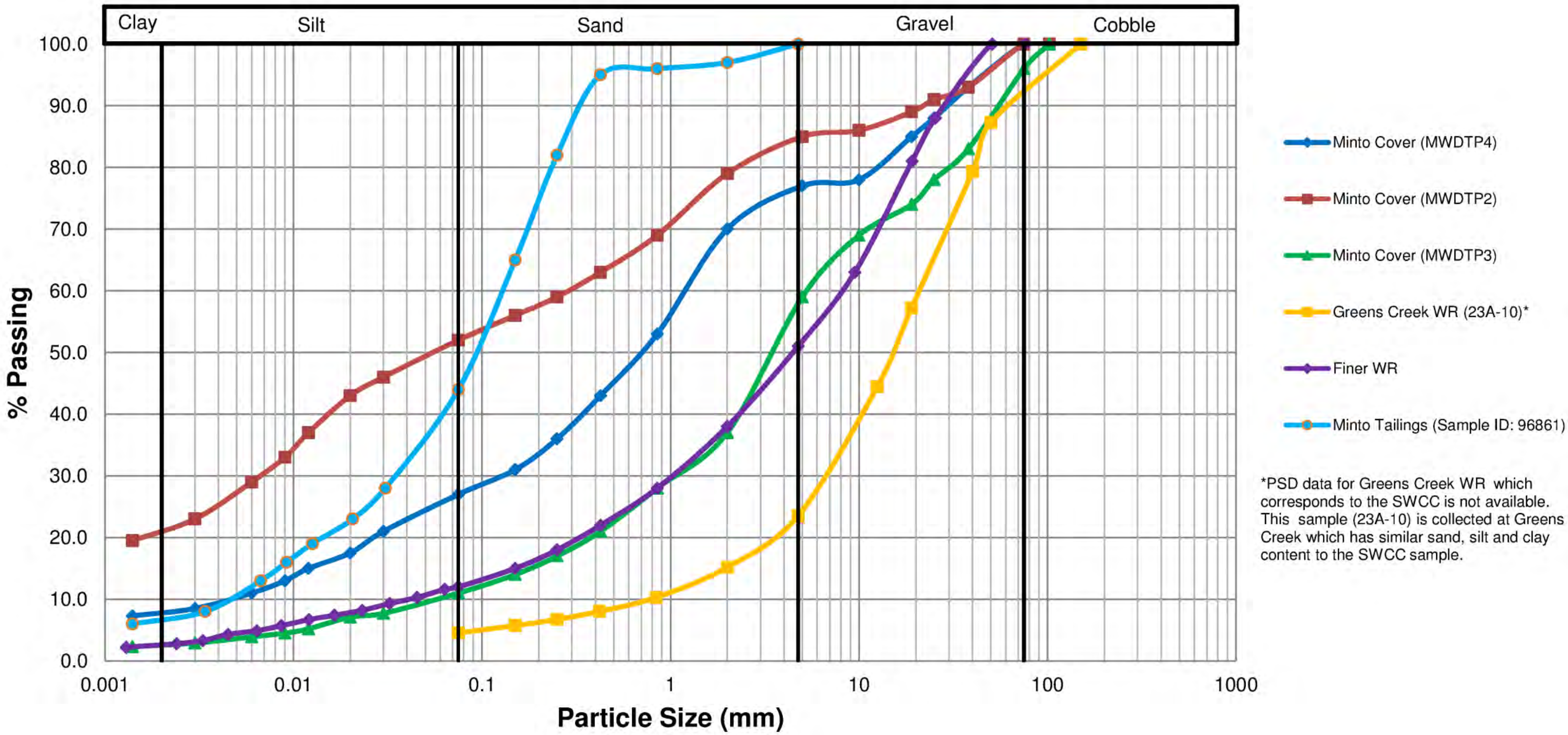

*PSD data for Greens Creek WR which corresponds to the SWCC is not available. This sample (23A-10) is collected at Greens Creek which has similar sand, silt and clay content to the SWCC sample.

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Closure Covers Model

PSD Curves of Selected Cover Materials, Waste Rock, and Tailings

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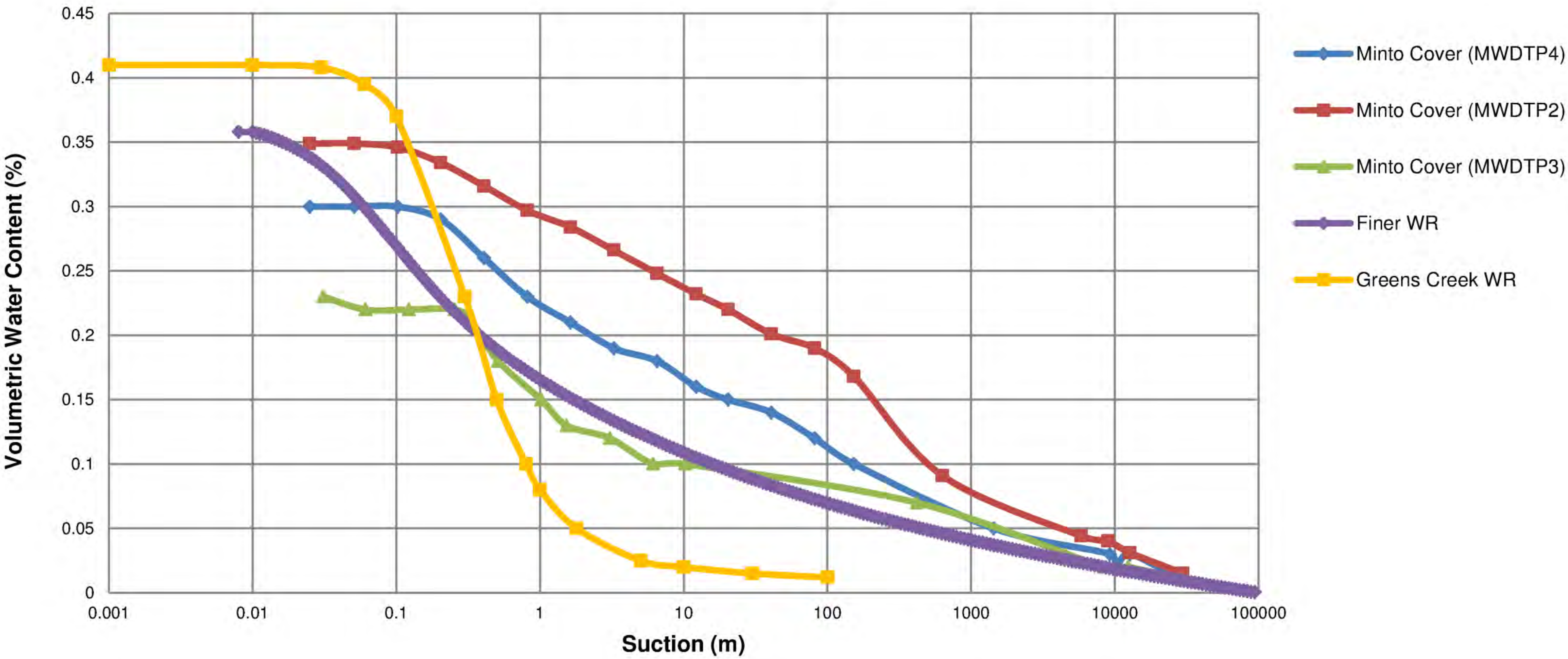

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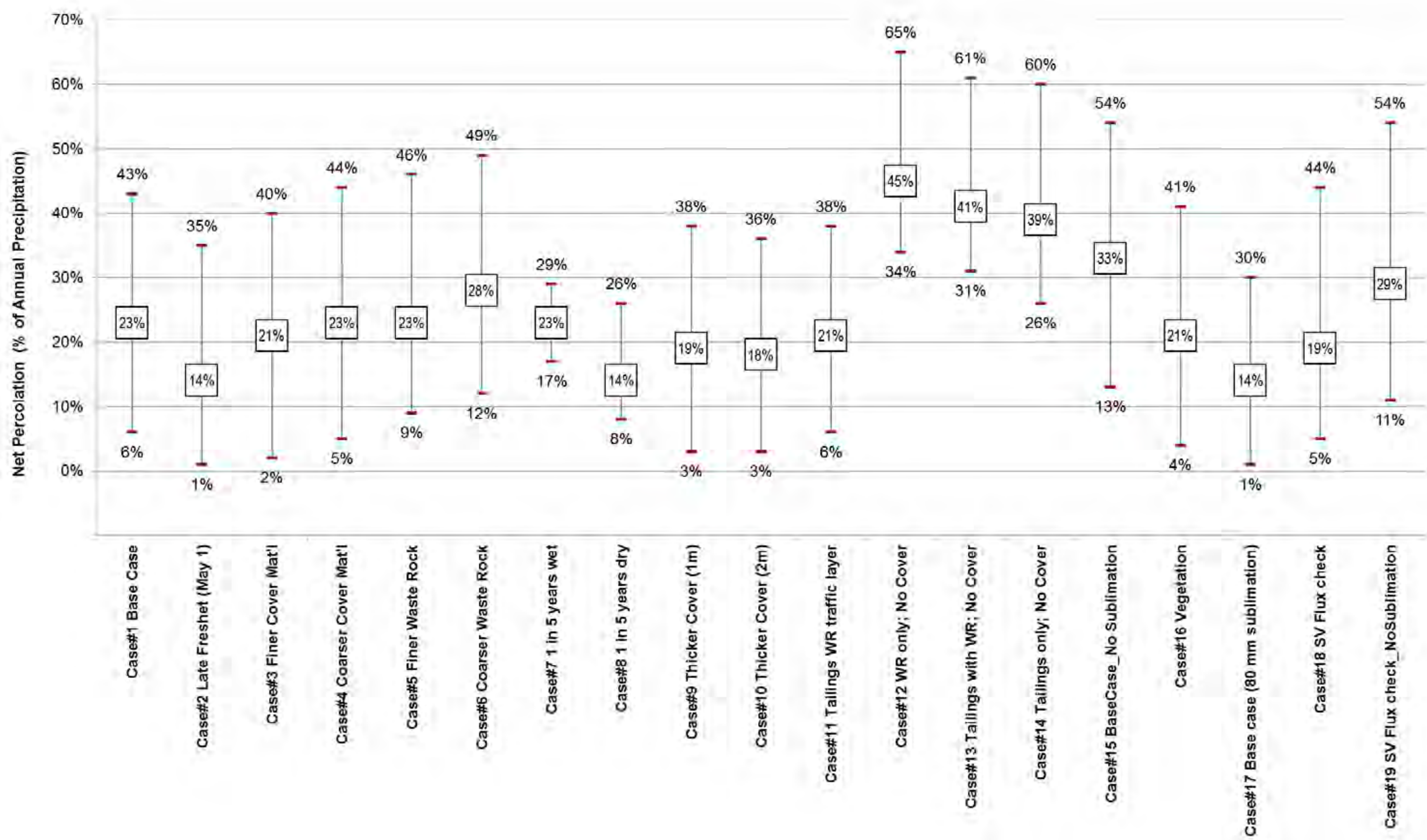

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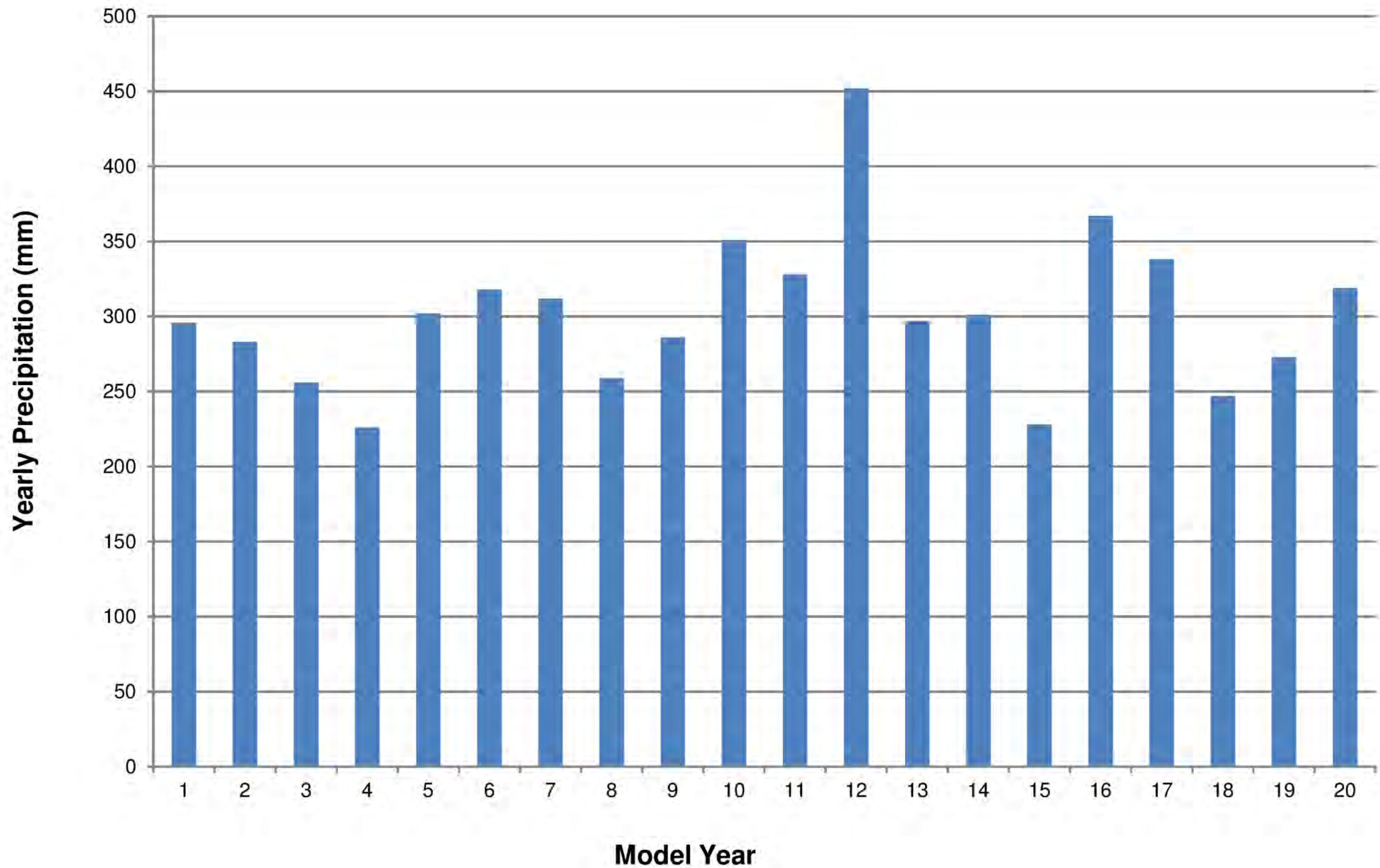

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Closure Covers Model

Normal Distribution of Yearly Precipitation

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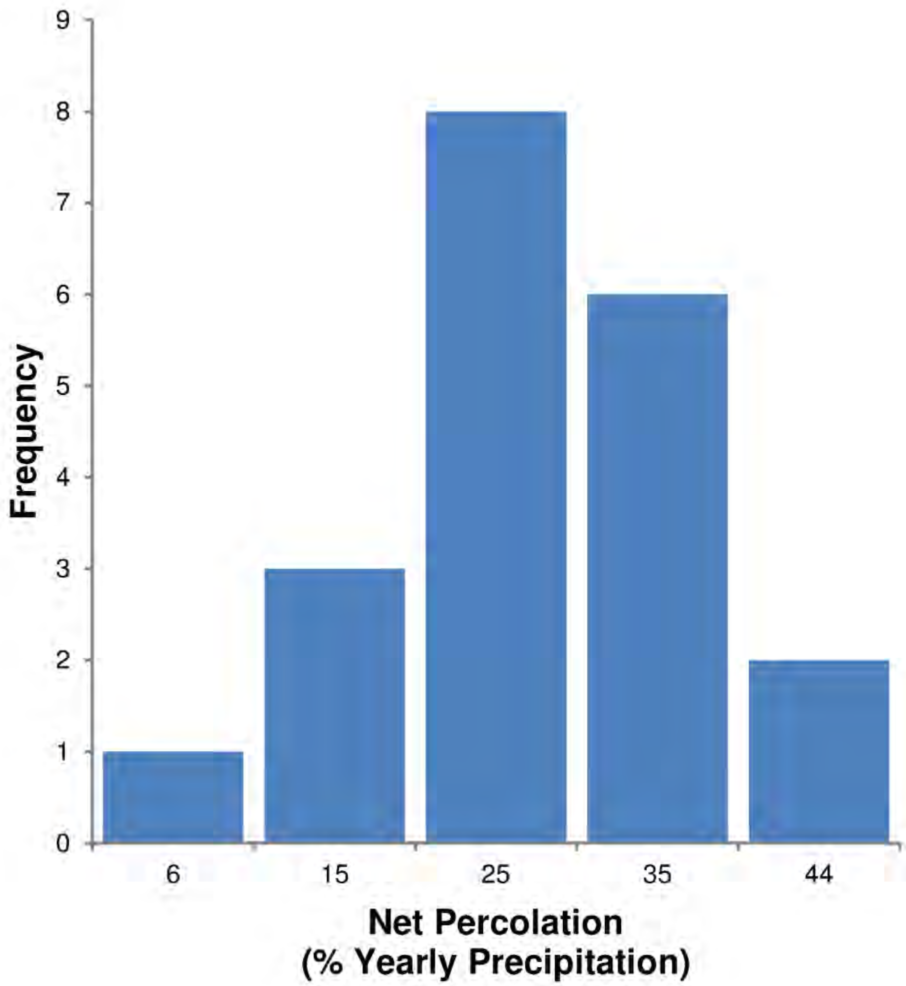

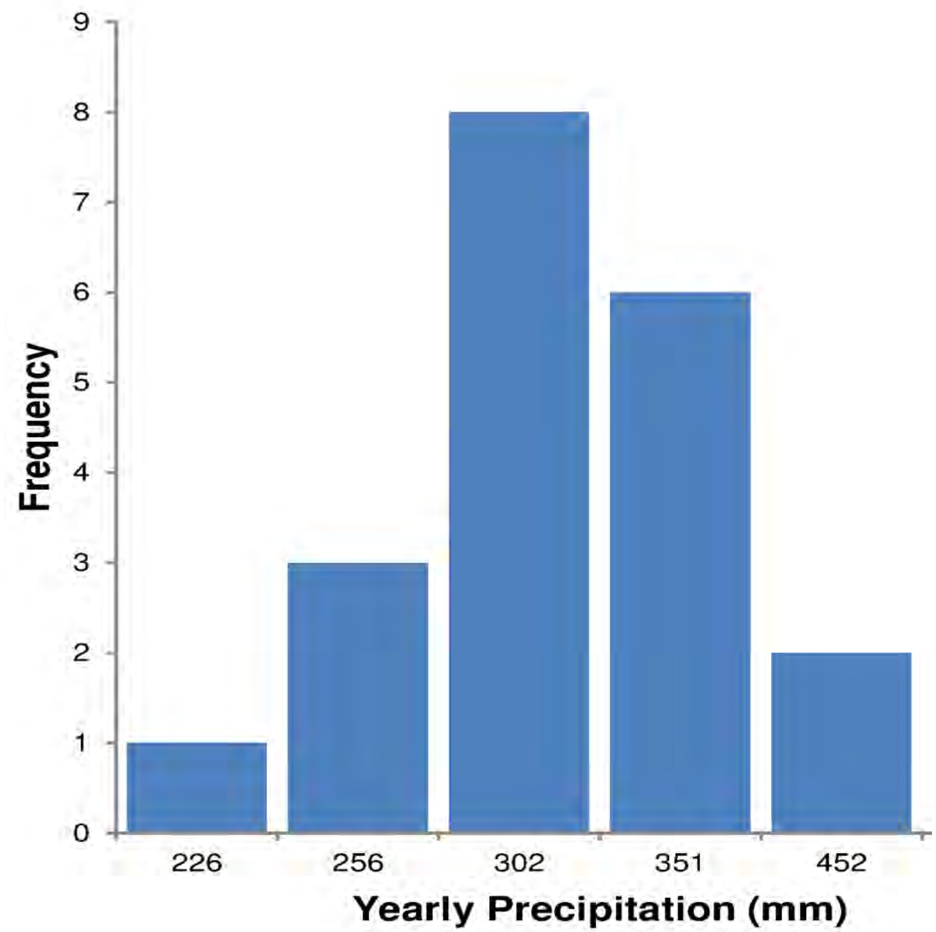

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Comparison of Statistical Distribution of Net Percolation and Precipitation

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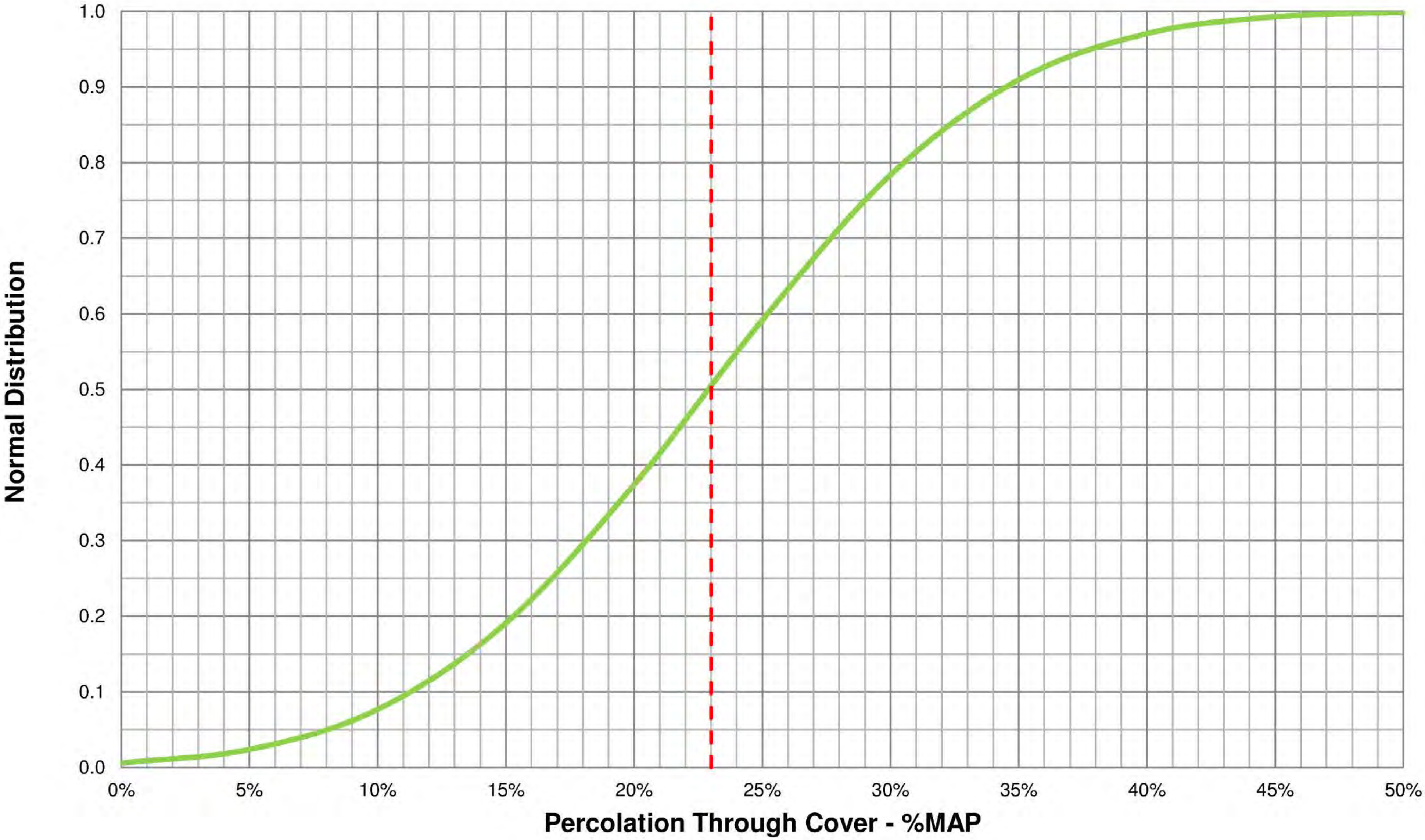

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Closure Covers Model

Percolation Through the Cover System

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Appendix E3
Updated Closure Cover Design for the Minto Mine 2018 Reclamation and Closure Plan

Updated Closure Cover Design for the Minto Mine 2018 Reclamation and Closure Plan

Prepared for

Minto Explorations Ltd.

Prepared by

SRK Consulting (Canada) Inc.
1CM002.049
January 2018

Updated Closure Cover Design for the Minto Mine 2018 Closure and Reclamation Plan Update

January 2018

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Project No: 1CM002.049

File Name: CoverDesign-Minto2018_1CM002-049_20180130_EK_dbm

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Executive Summary

This report provides updated closure cover designs for the Southwest Waste Dump; Ridgetop Waste Dump; Ridgetop South Pit Backfill Dump; Ridgetop North Pit; Dry Stack Tailings Storage Facility; the Mill Valley Fill, and Mill Valley Fill Extension Stage 1 and 2; the Main Waste Dump, Main Waste Dump Expansion, and Main Waste Dump Wrap; Main Pit Dump; subaerial Main Pit tailings; and the Area 118 Backfill Dump. This document is considered the most current closure cover design, and has been completed in consideration of all previous work.

Several additional structures were incorporated into this version of the closure cover design, and aspects of the closure design have been advanced from previous work, most notably the hauling of cover materials from the Area 2 Stage 3 Pit, and the purchase of revegetation seed mixes.

This document shows the reader how a minimum cover thickness of 0.5 m was determined and, based on the re-grading plans presented, how it results in a total cover volume requirement of approximately 1,077,300 m^3; of which the majority of material has already been hauled to the Southwest Waste Dump, the DSTSF, the Main Waste Dump, and the Mill Valley Fill. Area 118 is also received off-spec overburden materials as backfill. The remaining cover volume is well within the estimated 2.3 Million bank cubic metres of cover material available for use from the reclamation overburden dump. The closure covers are to be constructed of material with no less than 10% silt and clay sized particles. In general, the re-grading of the facility was completed to provide a cut/fill balance targeting overall slopes as shallow as possible.

The stability analysis indicates that slopes shallower than 3H:1V are anticipated to be stable in the long term, but should slopes of 2.5H:1V be proposed, additional work is necessary to confirm these slopes will be stable.

The erosion analysis has concluded that bare (unvegetated) site cover material is highly susceptible to erosion on slopes; therefore, establishing a vegetated cover is important to the success of the cover. The proposed revegetation plan for slopes is anticipated to consist of seed mixes of native grasses, and application of fertilizer in support of establishing a strong vegetative cover to reduce the potential for sheet erosion and gully development on the cover. In areas where slopes are flatter, such as facility tops and benches, the revegetation plan is intended to include seeding of native plant communities.

The ability for each facility to shed and direct water was considered against a 1:200 year flood event. The approach adopted for the tops of structures was to limit the flow to less than 1 m^3/sec, such that armoured channels or swales would not be required, but that erosional protection could be achieved through vegetation. The flow directed over slopes was intended to be rip-rapped, with detailed specifications or riprap thickness to be established at a later date.

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Appendices

1 Introduction

The Minto Mine is a high-grade copper mine located in the Yukon, approximately 240 km north of Whitehorse. The mine site occupies the valley in the upper reaches of Minto Creek, a tributary on the west side of the Yukon River. Operations began in October 2007 and are currently ongoing (2018).

Initially tailings were deposited in the Dry Stack Tailings Storage Facility (DSTSF) which was completed in 2012. Currently tailings and process water are managed in the Main Pit Tailings Management Facility (MPTMF) and the Area 2 Pit Tailings Management Facility (A2PTMF). In future, slurry tailings will be stored in the Ridgetop North Pit TMF, which will be utilized once mining is complete. Various waste rock storage facilities exist across the site including the Main Waste Dump (MWD), Main Waste Dump Expansion (MWDE), Main Pit Dump (MPD- active), Southwest Waste Dump (SWD), Ridgetop Waste Dump (RWD- planned), Area 118 Dump (active), and the Mill Valley Fill (and 2 extensions) (together, MVFE). Figure 1 illustrates these site facilities at the site.

1.1 Background

Numerous previous documents have been completed in support of various levels of closure planning. The most relevant document considered in support of this document include:

- Updated Closure Cover Design for the Minto Mine 2016 Closure and Reclamation Plan Update. SRK 2016c.
- Dry-stack Tailings Storage Facility Interim Cover Investigation. SRK 2016a.
- Closure Landform Design and Reclamation Landform Units for the Minto Mine. SRK 2016b.
- Minto Mine Closure Covers: Results of Numerical Modelling to Bracket Percolation Predictions. SRK 2015.
- Scoping Level Cover Assessment for Minto Closure Covers. SRK 2013a.
- 2012 Overburden Characterization Data Report for Minto Closure Covers. SRK 2013b.

This document has been prepared with the understanding that the above-mentioned reports are available to the reader and that should the reader choose, all relevant background to the cover designs is described.

Key conclusions from previous work have included:

- Cover materials placed without appropriate erosion protection are erodible and susceptible to gully development on the cover.
- The fine grained and mixed materials used to construct the interim cover of the DSTSF are suitable for use in the construction of final cover, but some revegetation efforts are necessary

to achieve cover functionality. The Residuum material is not a suitable stand-alone cover material as it cannot readily establish vegetation (SRK 2016a).

- The natural materials on-site are not expected to be capable of meeting the performance specifications of a low-permeability cover. Should a low-permeability cover be required, other options (including a geosynthetic) should be considered (SRK 2013a).

1.2 Advancements since the 2016 RCP

Minto has been advancing the progressive reclamation of the waste dumps with the direct hauling of overburden from the Area 2 Stage 3 Pit. Overburden materials that met the cover material specification (SRK 2016c) were hauled to:

- the Southwest Waste Dump
- the Main Waste Dump Expansion
- the Dry Stack Tailings Storage Facility, and
- the Mill Valley Fill Extension.

Materials that did not meet the design specification were wasted.

In addition to the direct hauling of overburden to the waste dump facilities, revegetation work continues to advance. Minto has purchased and is storing on-site sufficient seed to revegetate the slopes after the final cover placement has been concluded. The seed mix was specified on the basis that an initial vegetative cover could be developed to minimize the potential for erosion of the cover materials, and natural vegetation endemic to the region would establish over time.

The mine life has been extended to include the Area 2 Stage 3 pit, the Ridgetop North and South pits, and additional underground resources. This has resulted in modified designs (from SRK 2016c) to the Main Pit Dump, Main Waste Dump, the Area 118 Pit Backfill Dump, and the inclusion of the Ridgetop Waste Dump and the Ridgetop South Pit Backfill Dump. Minto also plans to mill the remaining high-grade waste portion of the Southwest Waste Dump[1], and to relocate SAT material currently stored in the Main Pit above elevation 786 m and place it below elevation 786 m so that it will be saturated over the long term.

1.3 Scope of Work

This report has been prepared to propose updated closure cover designs for the Southwest Waste Dump; Ridgetop Waste Dump; Ridgetop South Pit Backfill Dump; Ridgetop North Pit Tailings Management Facility; Dry Stack Tailings Storage Facility; Mill Valley Fill, Mill Valley Fill Extension Stage 1 and 2; Main Waste Dump, Main Waste Dump Expansion; Main Pit Dump and Main Pit Tailings Management Facility; and the Area 118 Backfill Dump. This document is considered the most current closure cover design, and has been completed in consideration of all previous work, while continuing to advance the level of detail in the engineering. This report

[1] A portion of the high grade waste originally stored in the Southwest Waste Dump has already been milled.

supersedes previous cover designs for the project including the designs proposed in previous closure plans.

This report is structured to lead the reader through descriptions of the closure cover objectives and criteria: the cover material characteristics, including overburden characterization, cover material thickness, erosion loss estimates, physical stability analysis, grading designs, water conveyance considerations, and re-vegetation descriptions for each of the above referenced facilities.

2 Objectives and Criteria

2.1 Design Objectives and Functions

It is currently proposed that the primary cover functions will be to:

- Reduce infiltration to the extent practical using locally available material;
- Ensure a stable landform that will promote establishment of natural vegetation endemic to the area; and
- Minimize ponding and surface erosion on the final landform.

2.2 Design Criteria

The proposed design criteria for closure covers at the Minto Mine are outlined in Table 1.

Table 1: Design Criteria

Component	Criteria	Comment/Rationale
Design Life	100 years.	Discussions related to closure often infer that closure measures (the soil cover, in this case) must last into perpetuity. While it is recognized that the cover will remain in place for a very long period, performance cannot credibly be measured in geologic timelines. Setting a realistic standard allows measurable targets to be set.
Oxygen Reduction	Not a defined criterion.	Oxygen reduction using covers is difficult to achieve in practice at the scale of full facilities. Instead, operational waste management practices have resulted in the majority of waste rock with NP:AP values below 3 being stored under conditions that will be saturated in the long term.
Infiltration Reduction	Not a defined criterion.	Minto and other project stakeholders wish to reduce infiltration (and net percolation) to the extent possible based on the available cover material's physical properties. The results of the cover modelling (SRK 2015) indicate that the net percolation is approximately 23%, but depending on the climactic conditions, can vary from 6% to 43%. Additional discussion is provided in Section 3.2.
Load Reduction	No specific target.	The site wide water and load balance assumes 20% net percolation through the cover over the long term, but acknowledges that net percolation (and therefore loading) may be greater or lower, depending on the climactic conditions.
Settlement	No criteria.	Settlement of the covers is not anticipated to occur as there is no settlement anticipated in the immediate foundation materials (waste rock, and compacted tailings). Long term thaw of permafrost foundations is expected to occur very slowly and to have little effect on cover performance.

Component	Criteria	Comment/Rationale
Seismicity	1 in 475-year recurrence interval.	Consistent with the BC Mined Rock and Overburden Piles Investigation and Design Manual, May 1991.
Physical Exposure	As far as practicable keep tailings and peripheral areas covered. At no time may more than 2.0 m^2 of mine waste be exposed as a contiguous area for the life of the structure.	It is recognized that the cover will evolve over time and factors such as extreme surface runoff beyond the stated design criteria, burrowing animals or human activities may cause damage to the cover.
Slope Stability	Overall factor of safety for the cover of 1.1.	Consistent with the BC Mined Rock and Overburden Piles Investigation and Design Manual, May 1991.
Wind Erosion	No criteria.	Based on site observations, wind erosion is not problematic.
Overland Surface Runoff	Capable of withstanding 1:200 year, 24-hour duration storm during peak freshet with no damage. An average soil loss of <6 tonnes/hectare /year is target from slopes, following the establishment and implementation of erosion mitigation strategies, such as vegetation. In no areas may overall cover thickness be less than 75% of original design thickness for the life of the structure.	Intend to construct a cover that could meet a soil erosion classification of Very Low (Wall et al. 2002)
Evapo-Concentration	No defined criteria.	Evapoconcentration is not expected to be an important post-closure process at Minto.
Root-Uptake	No defined criteria.	Root-uptake of porewater is not expected to be problematic, as there is no evidence of issues related to this on current revegetated areas.
Vegetation	Self-sustaining vegetation cover native to the region within 30 years of initial revegetation.	In areas of potential erosion concern (i.e. sloped cover facets), revegetation will focus on the rapid establishment of herbaceous ground-cover species using a mix of native grasses and one or more agronomic legumes, coupled with fertilizer applications in the early years (1-3) of establishment. In areas not targeted for the erosion-control treatment (i.e., landform plateaus and benches), revegetation will focus on re-establishing locally common native plant communities. Use of fertilizers on these areas will likely be avoided or minimized.
Land Use	General wilderness area. Large and small terrestrial animals, birds and aquatic life will be present. Humans will travel through the area infrequently (mostly hunters and trappers). Specific measures to preclude damage to the covers due to human and/or animal use is not required.	Wildlife habitat suitability will vary by vegetation type and structural stage as the vegetation becomes established and evolves.

Component	Criteria	Comment/Rationale
Landform	Promote use of landforms consistent with the current landscape. Provide for variability on cover thicknesses and landscaping as necessary to promote establishment of microclimates and variability.	The Closure Landform Design and Reclamation Landform Units for the Minto Mine will be used to guide the practical application of the landform design.

3 Cover Material Characteristics

3.1 Overburden Characterization

3.1.1 Geotechnical Characteristics

SRK evaluated 167 particle size distribution analyses and 38 Atterberg Limit (liquid and plastic limit) analysis completed on overburden samples at the Minto Site. Data was obtained from investigations completed, and documented by SRK (SRK 2013, 2016a&b). The data was reviewed, and indicated that in general the material can be variable from a particle size distribution perspective, with the amount of fines (less than 0.075 mm) in samples ranging between less than 5% to greater than 95%. Generally, the majority of the material that exists within the existing overburden stockpiles is expected to be in the range of 10% to 75% fines. Fines are used as a key indicator of the material as it can be used in the correlation of many soil parameters, including the moisture retention capacity of a soil. Typically, residuum samples were identified to have less than 10% fines. Residuum is a weathered bedrock material that has the consistency of a sand, and is typically a material that can be identified visually.

The Atterberg Limits are utilized to characterize the material in accordance with the Unified Soil Classification System (USCS) and the Modified Unified Soil Classification System (MUSCS). The material classifications generally range between CL-ML (Clayey Silt) to CL (Clay), which indicates the soils to have low to intermediate plasticity, and in the case of an ML (Silt), the behaviour is dominated by the silt sized particles present. The residuum material was deemed to be non-plastic.

For additional details related to the characterization of the geotechnical characterization of the overburden materials, refer to Appendix A.

3.1.2 Erosion

Soil erosion classification is based on the USDA soil textural classification. Table 2 provides a summary of the particle size diameter range based on the USCS / MUSCS, and the United States Department of Agriculture (USDA) soil textural classification.

Table 2: USCS vs USDA Particle Size Distribution Systems

Soil Component	Particle Size Diameter Rage (millimeters)	
	USCS / MUSCS	**USDA**
Boulders	> 200	n/a
Cobbles	200 – 76	n/a
Gravel	76 – 4.75	n/a
Sand	4.75 – 0.075	2.0 – 0.05
Silt	0.075 – 0.002	0.05 – 0.002
Clay	< 0.002	< 0.002

The samples were re-classified, and plotted on a soil texture triangle to determine the general soil texture. The samples typically categorized as sandy loam. For additional details related to the characterization of the soil classification of the USDA methodology, please refer to Appendix A.

3.1.3 Quantities

The reclamation overburden dump (ROD) contains approximately 2.3 Million bank cubic metres (EBA, 2010) of overburden. The overburden was characterized prior to mining, and a summary of the material properties is provided in Appendix A. The PSD of the material recovered from Area 2 is listed in Tables 2 and 3. Generally, the overburden material was not selectively placed within the ROD during placement, and material that would be excavated from the ROD for cover purposes is expected to be somewhat variable in quality, but with greater than 10% fines.

The overburden characterization from the Area 2 Stage 3 Pit indicated that the material is similar to the overburden currently contained in the ROD, but with some samples containing higher degrees of clay and silt. Based on the investigation completed, there were no mineable units within this area that were discretely targeted to produce material of higher or lower fines content. A more detailed description of the investigation and results is provided in Appendix B.

In 2014 overburden fine grained soils and residuum was place on portions of the DSTSF as a trial overburden cover. Those areas capped predominately with residuum did not support vegetation, and therefore did not meet the cover objectives. Areas of fine grained soils, and areas of mixed fine-grained soils and residuum do support vegetation and therefore do meet the cover objectives.

3.2 Cover Thickness to Achieve Net Percolation Targets

SRK completed numerical modelling to bracket percolation predictions in 2015 (SRK 2015). The modelling indicated that without a cover, the net percolation could be between 39% percent and 45%, and depending on climactic conditions, could vary between 26% and 65%. Cover materials were applied, with the base case cover material consisting of material properties from sample MWD-TP4 collected at the Minto Mine, which is a gravel and sand material with more than 25% fines (<0.075 mm). The results indicate that the net percolation is approximately 23% (under Mean Annual Precipitation (MAP) conditions), but depending on the climactic conditions, can vary from 6% to 43%. The cover material was varied and an analysis was also completed considering a coarse material (MWD-TP3), which is predominantly gravel and sand with less than 10% fines (<0.075 mm). The results of this analysis indicate that the net percolation was approximately 23%, but depending on the climactic conditions, can vary from 5% to 44%.

The modelling results indicate that there is roughly a 50% decrease in net percolation (from around 40% MAP to around 20% MAP) after cover materials are included in the analysis. The cover thickness was assumed to be approximately 0.5 m thick, and following sensitivity analysis to the thickness (1 m and 2 m) only minor additional decreases in net percolation were projected. Therefore, a minimum cover thickness of 0.5 m was adopted for the project, with a requirement that the materials contain greater than 10% fines.

3.3 Erosion Loss Estimate

The purpose of this analysis was to present the potential effects of erosion due to sheet and rill water erosion that could occur on the engineered slopes at Minto, and evaluate a range of conditions and parameters to help guide the landform designs. Sheet and rill erosion occurs as a result of flows that are not concentrated into a particular flow path, but over time, if allowed to persist, can develop into larger erosion features such as gullies. The intent is then to determine which methods of erosion protection are sufficient to reduce erosion to acceptable levels, to minimize the potential for development of gullies, and to characterize what (if any) sacrificial thickness should be added to the cover to account for erosion. This section provides a summary of the erosion loss analysis completed, with additional details found in Appendix C.

Erosion that may occur within channel flow and the associated armouring is not considered in this discussion.

Based on the RUSLEFAC equation, SRK has targeted a soil erosion classification of “Very Low” which means that an acceptable rate of erosion loss is approximately 6 Tonnes per hectare per year (Wall et al. 2002). Soils with erosion classifications of “Very Low” demonstrate slight to no erosion potential. Minimal erosion problems should occur if good soil conservation management methods are used. A tolerable soil loss (<6 T/ha/year) is the maximum annual amount of soil which can be removed before the long term natural soil productivity of a hillslope is adversely affected (Wall et al. 2002). By targeting a soil erosion classification of “Very Low”, the intent is to limit the development of rill, inter-rill, and ultimately gully erosion. In some cases, a soil can meet this target on its own, but in many cases, as is the case at the Minto site, support practices are required to achieve this target.

As described in Appendix C, soil loss over the course of the design life (100 years) was calculated to determine whether the average depth of soil loss would reduce the initial cover thickness to below the required cover thickness. The soil loss was calculated for unvegetated (bare) soils, and for soils with 80% coverage with short rooted plants. As is observed on the vegetation trials on the Main Waste Dump, under appropriate conditions, this can easily be achieved.

Annual soil loss due to water erosion was multiplied by 100 years to determine design life soil loss, which is presented for several straight slope scenarios in Table 3. Construction of complex slopes was calculated to have a potential impact on decreasing erosion by approximately 10%, which is discussed further in Appendix C. Average annual soil loss (in T/ha/year) is also presented in Table 3.

Table 3: Calculated Water Erosion Design Life Soil Loss

Slope Condition		Design Life Soil Loss (mm) per Slope Length							
		50 m		85 m		100 m		150 m	
		Annual (T/ha/yr)	100 yrs (cm)	Annual (T/ha/yr)	100 yrs (cm)	Annual (T/ha/yr)	100 yrs (cm)	Annual (T/ha/yr)	100 yrs (cm)
Non-Vegetated	**2.5H:1V**	31.8	19.9	41.8	26.1	45.6	28.5	56.2	35.1
	3H:1V	26.2	16.4	34.1	21.3	37.1	23.2	45.5	28.4
	3.5H:1V	22.1	13.8	28.6	17.9	31.0	19.4	37.8	23.6
	4H:1V	19.0	11.9	24.3	15.2	26.4	16.5	31.9	19.9
	5H:1V	14.6	9.1	18.4	11.5	19.8	12.4	23.7	14.8
Vegetated (80% Short-Rooted Plant Coverage)	**2.5H:1V**	3.7	2.3	4.8	3.0	5.3	3.3	6.5	4.1
	3H:1V	3.0	1.9	3.9	2.5	4.3	2.7	5.2	3.3
	3.5H:1V	2.6	1.6	3.3	2.1	3.6	2.2	4.4	2.7
	4H:1V	2.2	1.4	2.8	1.8	3.0	1.89	3.7	2.3
	5H:1V	1.7	1.1	2.1	1.3	2.3	1.4	2.7	1.7

Table 3 illustrates the value of vegetation, and therefore the establishment of vegetation on the slopes is critical to the success of the closure covers. Short term support practices will be required to develop a good vegetated cover. Examples of short term support practices are rolled erosion control products, slope texturing, and hydro-seeing with an erosion resistant tackifier. The potential effect that short term support practices have on reducing cover erosion are discussed in further detail in Appendix C. Once vegetation is established, the calculated soil loss is less than 5 cm, which is generally within the placement tolerance of earthworks when using large equipment and is therefore considered both negligible and acceptable.

3.4 Physical Stability

SRK evaluated the cover stability of the closure covers at various slope angles to identify if some of the available borrow material is better suited to some areas versus others. The global stability of the operational design of each of the waste facilities, under both operations and closure conditions, have been previously evaluated in their respective design documents. Generally, closure configurations will result in re-sloped/landscaped configurations with shallower slopes. Global stability is not considered further in this analysis, but may be considered further following the development of final re-grading plans discussed in this document.

Generally, the physical stability of a cover is a function of the normal stress over the cover, the internal shear strength of the cover material, the interface shear strength between the underlying material and the cover material, as well as the seepage forces present within the cover. In the case of most of the Minto cover designs, a lower strength cover material is proposed to be placed over a material with higher strength – either compacted tailings, the compacted shell of the DSTSF, or waste rock. Therefore, the critical failure mode is a failure that occurs along the interface of the two materials, and is controlled by the shear strength in the weaker cover material.

SRK completed a 2-dimensional limit equilibrium analysis stability analysis as described in Appendix D. The analyses were focused on base case scenarios where a piezometric surface was placed midway through the cover thickness, and the material underlying the cover was considered impenetrable to force the cover failure either through the cover material, or along the interface. Two sets of analyses were completed to demonstrate the effect of a cover constructed of residuum material versus a cover constructed of silty sand material. Analyses were completed for slopes of 2.5H:1V, 3H:1V, 4H:1V, and 5H:1V. Various sensitivity analysis was completed, which indicated that the models were most sensitive to the piezometric surface in the cover.

All of the base case scenarios met the minimum target factor of safety with the exception of the placement of a silty sand cover material on a 2.5H:1V slope. Additional analyses to evaluate the impact of a variable piezometric surface in the cover placed over a 2.5H:1V slope were completed as the base case conditions for the silty sand cover did not meet the minimum target factor of safety. The results indicated that increases in the piezometric surface decreased the factor of safety below the base case, while decreases in the piezometric surface increased the factor of safety above the target criteria.

The analysis concluded:

- Residuum material is preferable to be placed on a 2.5H:1V slope from a geotechnical stability perspective. Erosional susceptibility of the material (as discussed in Appendix C) and its ability to support re-vegetation efforts should be considered prior to final selection of cover material. It should also be noted that currently the Main Waste Rock Dump has 2.5H:1V slopes, and has been covered with silty sand material, and vegetation trials are on-going. The cover material does not appear to be prone to continued sloughing or cover failure, and it is likely that the waste rock below drains the cover and limits the potential for the piezometric level to increase to such a point that the seepage forces influence the cover stability below unity. Vegetation on the cover varies from well covered to sparsely covered.
- Slopes of 3H:1V, or shallower are not restricted to the type of cover material based on geotechnical performance.

3.5 Design Parameters

Table 4 provides a summary of proposed design parameters to be adopted for the Minto Closure Covers, based on the particle size distributions, and the net percolation cover modelling completed (SRK 2015).

Table 4: Closure Cover Design Parameters

Description		Value
Cover Thickness		0.5 m (minimum)
Cover Material Specifications	Gravel	0 % to 40%
	Sand	60% to 90%
	Fines	> 10%
Soil Texture Classification	Sandy Loam	Sandy Loam

4 Revegetation

The preliminary revegetation plan is designed to achieve the land-use objectives of wildlife habitat re-creation, creation of habitat for traditionally used plants, and the return of biodiversity values over time. The primary focal wildlife species is moose, although re-creation of habitat for prey species such as snowshoe hare and upland game birds may be possible. Revegetation treatments are designed to achieve these objectives, and also to perform the key task of protecting the placed cover materials from erosion where required. Classification of the revegetation objectives are as follows:

1. Slopes versus plateaus – a primary goal of revegetation is to reduce erosion, where needed. Thus, we identified sloped areas for erosion-control revegetation treatments and level areas where these treatments are not required; and
2. Zonal(mesic) sites versus drier (subxeric-submesic) sites – the former occur on tailings substrates and north-facing slopes, while the latter occur on waste-rock substrates and south-facing slopes.

Mapping of the area indicated that approximately 42 ha of level/plateau areas and 38 ha of sloped areas will be ready for revegetation in 2018. Seed mixes were designed for these areas based on the following principles, with the overarching objective that revegetation materials should be wholly or mostly made up of species native to the Yukon:

- **Sloped areas** – the primary revegetation goal on these areas is erosion control, so the seed mix should be primarily composed of native grass species, seeded relatively heavily (35 kg/ha), with an additional component of annual ryegrass and alfalfa, to accelerate revegetation and reduce the amount of bare ground exposed to erosion. Alfalfa was included as it is the only native legume still listed as an acceptable species by the Yukon Revegetation Manual (Matheus and Omtzigt 2013).
- **Level areas** – the primary revegetation goal on these areas is promotion of recovery towards pre-development ecosystems. For this reason, the primary revegetation strategy is natural regeneration, as this has been observed on many sites at Minto, and as the relatively small development footprint and proximity of non-mined seed sources facilitates this recovery mechanism. However, observations on the MWD revegetation trial and the naturally revegetating overburden stockpiles suggest that foxtail barley is present and readily able to colonize sites. This species is undesirable as a large component of revegetation, as it can cause problems for grazing wildlife after seed formation, as the long seed awns can get stuck in the mouth, nose, and eyes of grazing animals, potentially causing irritation and infection. Therefore, a seed mix was developed for level areas at Minto, with the goal of providing some occupation of space to prevent full colonization by foxtail barley, but also of leaving space for natural colonization of these sites. The level-ground seed mix is composed solely of grass species native to the Yukon, applied at a rate lighter (20 kg/ha) than that used for the sloped areas.

Yukon Energy, Mines and Resources (2013b) defines re-vegetation as the re-establishment of vegetation on land which previously had vegetation cover. The objective of revegetation of mining disturbances is "*to leave the ground in such a way as to provide a good chance for successful re-vegetation by plant species native to the site and the area (natural revegetation)".* It is anticipated that the two primary revegetation treatments proposed above for Minto are consistent with this over-arching objective. Native species tend to be slower to establish than agronomics (which have been selectively bred for rapid establishment), and with the high silt content and erosion susceptibility of the Minto cover materials, rapid revegetation is critical to minimize erosion and protect the cover material. Restriction to use of native species only would likely result in high erosion rates, loss of cover materials through sheet and/or rill/gully erosion, and likely subsequent poor revegetation. Targeted use of agronomics will promote cover stability at the ground surface, and will be more successful in eventually establishing native species. As excessive erosion would be a key failure mode for the cover system, the revegetation treatments have been developed to give priority to reduction of risk of this failure mode. A transition to native species on these erosion-control areas is anticipated to occur naturally, due to the focus on native-species establishment on other mine areas and due to the proximity of surrounding vegetation-propagule sources in adjacent intact ecosystems.

Additional detail on development of revegetation treatments, and associated recommendations, are provided in the technical memo attached as Appendix E. Minto has purchased, and has on-site seed to apply to the covers after it is determined that the minimum cover thickness has been placed. This is planned to occur in 2018.

5 Re-grading Designs

5.1 Southwest Waste Dump

Progressive reclamation of the Southwest Waste Dump began in 2015. Minto re-sloped the face of the dumps to slopes ranging roughly between 12H:1V and 4H:1V and has hauled and stockpiled overburden necessary to cover and revegetate the top of the dump, and the sump slopes. Remaining work to be completed includes:

- Spreading and grading of the overburden at the top of the dump, and the slopes;
- Grading on the top surface to shed water into swales designed to carry the flow down the face of the dump without causing significant erosion;
- Excavation of the high-grade waste stockpile (for either milling or relocation);
- Additional design work;
- Construction of swales;
- Cover placement; and
- Detailed planning and implementation of revegetation plans.

A minimum cover thickness of 0.5 m is proposed for the Southwest Waste Dump across the facility, including the footprint of the high-grade waste stockpile. Localized areas may require additional grading to meet design grades, and it is proposed that final grades will be achieved through the placement of overburden, subject to Minto's scheduling plans.

To shed water, the top of the medium grade waste area is proposed to be split into six catchment areas while the bulk waste area is proposed to be split into three small catchment areas. These catchment areas are illustrated in the detailed hydraulic analysis information contained in Appendix F. The intent is to minimize the amount of water that flows directly over the slope as sheet flow. Each of these small catchments would be constructed to direct water into a broad swale, currently considered to be 2 m wide at the base, and have side slopes of 10H:1V. The swales were designed based on contributing watershed area, and flow depths are anticipated to range between 0.13 m and 0.37 m during a 1:200 year 24-hour flood event. The reported depths are double that of the calculated depths to allow for ice accumulation; however, this is a conservative element, as no significant ice accumulation is anticipated given the expected unsaturated nature of the underlying waste rock and the lack of winter groundwater discharge to the channels.

The swales have been designed to flow over and maintain the same base with the slope, but transition to 3H:1V side slopes along the slopes. The swales on the top are proposed to be protected with vegetation, while the slopes are proposed to be armoured with a gravel to cobble sized rip rap. Rip rap thickness and final dimensions are yet to be determined. Details regarding the hydraulic designs of these swales are provided in Appendix F.

The proposed re-grading and swale locations are illustrated on Figure 2. The Southwest Waste Dump is expected to require approximately 322,200 m^3 of cover material. Of this, sufficient overburden has been hauled to the top of the mid-grade pile and stockpiled to achieve final grades, and to apply along the slope. It is estimated that over 60% of the material necessary to cover the Southwest Waste Dump has been hauled and stockpiled. The proposed slopes are 3H:1V or shallower, and therefore physical stability of the cover is not anticipated to be problematic.

5.2 Ridgetop Waste Dump

The design of the Ridgetop Waste Dump final grading is based on the permitted design of the dump. As construction of the dump has not yet started, the configuration of the as-constructed dump is not yet known. Remaining work to be completed includes:

- Additional planning and design work, using as-built dump surface details;
- Cover placement; and
- Detailed planning and implementation of revegetation plans.

Consistent with the Southwest Waste Dump design, a minimum cover thickness of 0.5 m is proposed across the facility. Localized areas may require additional grading to meet design grades, and the decision to achieve final grades by grading waste rock, or using overburden will be determined based on Minto's scheduling plans.

To shed water, the top of the Ridgetop Waste Dump is proposed to be split into three small catchment areas that direct water away from the slopes of the dump towards natural ground at the eastern side of the dump. These catchment areas are illustrated in the detailed hydraulic analysis information contained in Appendix F. The intent is to minimize the amount of water that flows directly over the slope as sheet flow. Each of these small catchments would be constructed to direct water into a broad swale, currently considered to be 2 m wide at the base, and have side slopes of 10H:1V. The swales were designed based on contributing watershed area, and flow depths are anticipated to range between 0.18 m and 0.37 m during a 1:200 year 24-hour flood event. The reported depths are double that of the calculated depths to allow for ice accumulation; this is conservative, as explained in Section 5.1 for the Southwest Waste Dump. The swales on the top are proposed to be protected with vegetation. Details regarding the hydraulic designs of these swales are provided in Appendix F.

No swales have been designed along the slopes of the dumps as there is no designed catchment to route along the slopes of the dump.

The proposed re-graded facility is illustrated on Figure 2. The Ridgetop Waste Dump is estimated to require approximately 194,500 m^3 of cover material. The proposed slopes are 3H:1V or shallower, and therefore physical stability of the cover is not anticipated to be problematic.

5.3 Ridgetop South Pit Backfill Dump

The design of the Ridgetop South Pit Backfill Dump final grading is based on the permitted design of the dump. As excavation of the pit, and construction of the dump has not yet started, the configuration of the as-constructed dump is not yet known. Remaining work to be completed includes:

- Additional planning and design work, using as-built dump surface details;
- Cover placement; and
- Detailed planning and implementation of revegetation plans.

Consistent with the other waste dump designs, a minimum cover thickness of 0.5 m is proposed across this facility. Localized areas may require additional grading to meet design grades, and the decision to achieve final grades by grading off-spec overburden, or using suitable cover material will be determined based on Minto's scheduling plans. It may be determined that suitable cover material for this dump will be residuum, which is consistent with the natural soils surrounding the dump.

To shed water, the top of the Ridgetop South Pit Backfill Dump is anticipated to shed away from the dump, to the west. An estimate of the catchment areas and swale sizing is provided in the hydraulic analysis information contained in Appendix F. Consistent with the designs for the other waste structure, the catchment would be constructed to direct water into a broad swale, currently considered to be 2 m wide at the base, and have side slopes of 10H:1V. The swale was designed based on contributing watershed area, and the flow depth was estimated to be 0.22 m during a 1:200 year 24-hour flood event. The reported depth is double that of the calculated depths to allow for ice accumulation; this is conservative, as explained in Section 5.1 for the Southwest Waste Dump. The swales on the top are proposed to be protected with vegetation. Details regarding the hydraulic designs of these swales are provided in Appendix F.

The Ridgetop South Pit Backfill Dump design has not been finalized. However, to ensure that here is appropriate cover material allocated for scheduling purposes, the proposed re-grading design was used to estimate the volume of cover material that may be required. The Ridgetop South Pit Backfill Dump p is estimated to require approximately 16,500 m^3 of cover material. The proposed re-grading is illustrated on Figure 2.

5.4 Ridgetop North Pit Tailings Management Facility

The Ridgetop North Pit has not yet been mined, and therefore the final configuration is subject to change based on the as-built condition. It is proposed that the Ridgetop North Pit will be backfilled with tailings, and referred to as the Ridgetop North Pit Tailings Management Facility. Final closure configuration of the Ridgetop North Pit does not include a water cover, and therefore a soil cover will be required to be placed over the tailings. It is proposed that the cover will consist of a rock trafficking layer and a 0.5 m thick overburden cover; however, detailed engineering has not been advanced for this concept. The rock trafficking layer is also intended to reduce the potential for boils to develop in the cover.

A preliminary plan for re-grading is illustrated on Figure 2. The proposed plan assumes that the cover will be placed at (or near) elevation 862 m, and that it will grade towards a central swale designed to carry water off of the facility. The broad swale is currently considered to be 2 m wide at the base, and have side slopes of 10H:1V. The swale was designed based on the contributing area of the Ridgetop North Pit, and is estimated to have a total depth of flow of 0.48 m. The reported depth is double that of the calculated depth to allow for ice accumulation; this is conservative, but as the tailings are expected to impede drainage of the cover, there is a higher probability of ice accumulation within this swale.

The re-grading plan for the facility accounts for an allowance of 1 m of trafficking layer, as it is anticipated some of the trafficking layer will be lost into the tailings, and 0.5 m of cover material. This results in a need for approximately 57,000 m^3 of material to provide the trafficking surface, and 28,500 m^3 of cover material to place over the trafficking surface.

5.5 Dry Stack Tailings Storage Facility

Progressive reclamation of the DSTSF completed to date has consisted of placement of an interim cover over the tailings. This served multiple purposes, including isolating the tailings from wind and water erosion, as well as informing the success of using different cover materials. Observation of the interim cover has led to the conclusion that residuum material on its own is not a preferred cover material; however, a mix of residuum and fine-grained overburden will be able to achieve the overall closure cover objectives. Select areas of the cover have been excavated to achieve the desired drainage grades, without adding additional mass (in cover material) that may detrimentally impact the stability of the DSTSF. In addition, the downstream shell of the DSTSF has been re-graded on the eastern side, and approximately 2/3 of the downstream shell has been re-graded along the northern side. Overburden material was stockpiled at the crest of the dump, and has been spread along areas where the dump face has been re-graded. Remaining work to be completed includes:

- Re-grading of the western end of the rock shell face of the DSTSF;
- Re-grading and surface material amendment on the top of the DSTSF;
- Confirmation that the surface material amendment placed meets the minimum cover thickness requirements;
- Additional design work related to final local drainage network details; and
- Detailed planning and implementation of revegetation plans.

A minimum cover thickness of 0.5 m is proposed for the DSTSF. To shed water, the top of the DSTSF is split into five catchment areas, intending to direct water off the facility to the west, north, and south-east. These catchment areas are illustrated in the detailed hydraulic analysis information contained in Appendix F. The intent is to minimize the amount of water that flows directly over the slope as sheet flow. Each of these small catchments would be constructed to direct water into a broad swale, currently considered to be 2 m wide at the base, and have side slopes of 10H:1V. The swales were designed based on contributing watershed area, and flow depths are anticipated to range between 0.12 m and 0.27 m during a 1:200 year flood event. The reported depths are double that of the calculated depths to allow for ice accumulation; this is conservative, as explained in Section 5.4 for the Ridgetop North Pit Tailings Management Facility.

Only one swale is proposed along the slopes of the DSTSF. This is proposed along the northern slope, and designed to carry water down the face of the DSTSF and onto the Mill Valley Fill Extension. Where this swale transitions from the top of the DSTSF to the face of the DSTSF, it will transition to a 2 m wide base channel with 3H:1V side slopes. The swales on the top are proposed to be protected by vegetation, while the swale on the slope is proposed to be armoured with a gravel to cobble sized rip rap. Rip rap thickness and final dimensions are yet to be determined. The proposed re-grading and swale locations are illustrated on Figure 2.

Soil loss due to erosion caused by overland sheet flow (as discussed in Section 3.3) has the ability to impact the integrity of the cover and it is proposed that the revegetation concepts described in Section 4 be implemented. The proposed slopes are 4H:1V or shallower, and therefore physical stability of the cover is not anticipated to be problematic.

The estimated cover volume necessary to cover the DSTSF is 111,900 m^3. All of this volume has been hauled to the DSTSF, and needs to be spread across the DSTSF top surface and shell, and confirmation of the final thickness to be completed thereafter.

5.6 Mill Valley Fill Extension Stage 1 & 2

The Mill Valley Fill Extension Stage 1 and 2 were designed with closure in mind. The top surfaces were generally graded to shed water towards the north.

There are three main terraces to the waste dump. The first westernmost terrace will require some effort to re-grade so that water is directed to the west, rather than to the north. The middle terrace is proposed to be graded north and will also convey water shed off the DSTSF (through constructed swales). The eastern terrace is proposed to be graded to shed water off to the north-west. The downstream slopes of the Mill Valley Fill Extension have been completed and closure cover placement has already begun. Closure cover placement and spreading has also begun on the top surfaces of the dumps. Remaining work to be completed includes:

- Cover placement along the slopes;
- Cover grading of the top dump surfaces;
- Swale construction;
- confirmation that the surface material placement placed meets the minimum cover thickness requirements;
- additional design work related to final local drainage network details; and
- detailed planning and implementation of revegetation plans.

Consistent with other facilities, a minimum cover thickness of 0.5 m is proposed and localized areas may require additional grading to meet design grades. Design grades may be achieved through the placement of either waste rock, or overburden based on Minto's scheduling plans.

To shed water, the top of this facility was separated into three small catchment areas, controlled by the surface area of each dump terrace. These catchment areas are illustrated in the detailed hydraulic analysis information contained in Appendix F. Consisted with the other facilities, the intent is to minimize the amount of water that flows directly over the slope as sheet flow. All three of these small catchments would be constructed to direct water into a broad swale, currently considered to be 2 m wide at the base, and have side slopes of 10H:1V. The swales were designed based on contributing watershed area, and flow depths of approximately 0.19 m to 0.39 m during a 1:200 year 24-hour flood event. The reported depths are double that of the calculated depths to allow for ice accumulation; this is conservative, as explained in Section 5.1 for the Southwest Waste Dump.

Consistent with the design philosophy employed with the other facilities, the swales have been designed to flow over the slope and transition to a channel base width equal to that of the swale on the top surface with 3H:1V side slopes. The swales on the top are proposed to be protected with vegetation, while the slopes are proposed to be armoured with a gravel to cobble sized rip rap. Rip rap thickness and final dimensions are yet to be determined. The proposed re-grading and swale locations are illustrated in Figure 2.

As discussed in Section 3.3, soil loss due to erosion caused by overland sheet flow can impact the integrity of the cover. However, it is proposed that the revegetation concepts described in Section 4 be implemented on the slopes to minimize erosion, and increase the rate of success for revegetation. The proposed slopes are 3H:1V or shallower, and therefore physical stability of the cover is not anticipated to be problematic.

The proposed plan includes approximately 71,300 m^3 of cover material, all of which has already been hauled to the dump.

5.7 Main Waste Dump and Main Waste Dump Expansion

Progressive reclamation began at the Main Waste Dump through the placement of cover material, and vegetation trials on two portions of the re-sloped benches. The trials have illustrated various level of success, but reinforces the conclusions from the erosion analysis: that without vegetative support, when placed on slopes the overburden material is highly susceptible to rill erosion, which has led to the development of gullies along the face where vegetation has not been successful. The re-graded slopes were re-graded to 2.5H:1V. An extension of the Main Waste Dump toe is currently under construction with waste rock, and is referred to as the Main Waste Dump Wrap. This will shallow the slope at the toe of the main waste dump to a minimum grade of 3H:1V.

The Main Waste Dump Expansion is currently being used as a location to stockpile overburden. Most of reclamation activities, including upgrade of the currently placed cover, remain to be completed. Re-graded slopes are proposed to be variable, and are currently designed to be as steep as 2.5H:1V (for short transition segments), and as shallow as 4H:1V.

Consistent with the overall theme of this document, a minimum cover thickness of 0.5 m is proposed recognizing that localized areas may require additional grading to meet the final design grades. Much of the dump slopes will require re-grading and, except for the south-east corner of the dump, this will be completed on a balanced cut-fill basis using the existing waste rock.

To shed water, the top of the Main Waste Dump Expansion has been designed to be split into two main catchments with water shed to the west. These catchment areas are illustrated in the detailed hydraulic analysis information contained in Appendix F. The intent is to minimize the amount of water that flows directly over the slope as sheet flow to that which falls and accumulates on the slopes. Each of these small catchments would be constructed to direct water into a broad swale, currently considered to be 2 m wide at the base, and have side slopes of 10H:1V. The swales were designed based on contributing watershed area, and flow depths were calculated to be between 0.14 m and 0.34 m during a 1:200 year 24-hour flood event. The reported depths are double that of the calculated depths to allow for ice accumulation; this is conservative, as explained in Section 5.1 for the Southwest Waste Dump.

The swales have been designed to flow over the slope, and transition to a 2 m wide base channel with 3H:1V side slopes. The swales on the top are proposed to be protected with vegetation, while the slopes are proposed to be armoured with a gravel to cobble sized rip rap. Rip rap thickness and final dimensions are yet to be determined. The proposed re-grading and swale locations are illustrated in Figure 2.

As discussed in Section 3.3, soil loss due to erosion caused by overland sheet flow can impact the integrity of the cover. Due to the size of the dump, and the length of the slopes, a variety of support practices have been adopted to reduce the overall erosion susceptibility of the slope. These support practices include complex slopes, benches to reduce flow velocity and provide areas of sediment deposition. Of critical importance will be the establishment of a strong vegetative cover early in the closure to further reduce the potential for erosion along the slopes. The short-term revegetation concept is described in Section 4.

The proposed plan includes approximately 231,800 m^3 of cover material, considering the additional surface area created with the shallowing of the dump toe (the Main Waste Dump Wrap). It is understood that approximately half of this volume has been hauled and stockpiled at the Main Waste Dump Expansion.

5.8 Main Pit Dump & Subaerial Main Pit Tailings

The Main Pit Dump is currently under construction and the final configuration of the dump has yet to be finalized. SAT material above elevation 786m (the planned final water level of the pit) is currently proposed to be relocated to areas within the pit where it can be covered with water (i.e. below elevation 786 m). Tailings were deposited in the Main Pit both subaqueously and subaerially, and some of these tailings are above the planned final water elevation of 786m, and as such require a cover.

A minimum cover thickness of 0.5 m is proposed over the Main Pit Dump. To shed water, the top of the Main Pit Dump has been designed to shed water towards the south-west. The catchment area anticipated to capture the flow is illustrated in the detailed hydraulic analysis information contained in Appendix F. A broad swale, with dimensions of 2.0 m wide at the base and side slopes of 10H:1V is currently proposed. The swale was designed based on contributing watershed area and the flow depth has been estimated to be 0.22 m during a 1:200 year 24-hour flood event, accounting for ice accumulation within the swale; this is conservative, as explained in Section 5.1 for the Southwest Waste Dump. A swale is also proposed to carry the water collected on the top surface down the slope. This swale has been designed to flow over the slope and transition to a channel with the same base width, but with 3H:1V side slopes. The swale on the top are proposed to be protected with vegetation, while the slopes are proposed to be armoured with a gravel to cobble sized rip rap. Rip rap thickness and final dimensions are yet to be determined.

A cover will be required for the subaerially deposited tailings which are expected to be above the high-water level in the pit at closure. These tailings will be covered with a rock trafficking layer and a 0.5 m thick overburden cover; however, detailed engineering has not been advanced for this concept. The trafficking layer will be designed with the intent of preventing boils from developing through the cover and preventing wave erosion of tailings where water depths are less than 1 m (i.e. above 785 m elevation). As a conservative measure at this point, a 20% increase in the overall area to be covered has been accounted for.

A preliminary plan for re-grading and the swale location is illustrated on Figure 2. The proposed plan considered as balanced cut-fill to re-grade the dump, and approximately 67,800 m^3 of cover material over the dump. The subaerial tailings are anticipated to require approximately 6,400 m^3 of cover material, and 12,800 m^3 of trafficking material.

As discussed in Section 3.3, soil loss due to erosion caused by overland sheet flow can impact the integrity of the cover. However, it is proposed that the revegetation concepts described in Section 4 be implemented on the slopes to minimize erosion, and increase the rate of success for revegetation.

The currently illustrated dump faces are at a minimum slope of 3H:1V, and therefore the physical stability of the cover is not anticipated to be problematic.

5.9 Area 118 Pit Backfill Dump

The Area 118 Pit Backfill Dump has been receiving off-spec overburden from the excavation of the Area 2 Stage 3 Pit. The proposed re-grading plan is intended to fill in the dump and shed water towards the Area 2 Pit, with slopes not steeper than 3H:1V. A minimum cover thickness of 0.5 m is proposed. It is currently proposed that the dump will be graded but not covered with additional material, as a final cover of residuum or fine grained material to match the surrounding hillsides would be appropriate.

The current grading concept separates the dump into three catchment areas (detailed provided in Appendix F). Broad swales with dimensions of 2 m wide at the base and side slopes of 10H:1V is currently proposed. The swales were designed based on contributing watershed area and the flow depth has been estimated to be between 0.08 m to 0.16 during a 1:200 year 24-hour flood event, accounting for ice accumulation within the swale; this is conservative, as explained in Section 5.1 for the Southwest Waste Dump. The swale is proposed to be protected with vegetation. Where the swales transition along the slopes, the side slopes will transition to 3H:1V and be armoured with gravel to cobble sized riprap. Detailed design of these swales has yet to be completed.

A preliminary plan for re-grading and the swale location is illustrated in Figure 2. The proposed plan includes approximately 26,400 m^3 of cover material.

As discussed in Section 3.3, soil loss due to erosion caused by overland sheet flow will be an important consideration for this facility, and the revegetation concepts described in Section 4 will be incorporated into the design.

The currently illustrated dump faces are at angles of 3H:1V or shallower, and therefore the physical stability of the cover is not considered to be problematic.

6 Conclusions

This document presents an updated design for the closure covers at the Minto site and supersedes any previous cover designs at the site. A description of how the design objectives and function were met is provided in the table below:

Design Objective and Function	Design Component
Minimize infiltration to the extent practical using locally available material.	Specifying a material particle size distribution demonstrated to meet appropriate reduce infiltration through numerical modelling (SRK, 2015).
Ensure a stable landform that will promote establishment of natural vegetation endemic to the area.	Analysis has been completed to demonstrate the erosion susceptibility of the proposed cover soils; however, methods to limit the erosion have been proposed. Analysis has been completed to determine the physical stability of the covers.
Minimize ponding and surface erosion on the final landform.	The grading plans developed have been done so to reduce the risk of surface water ponding, and flow velocities have been considered in completing the sizing of the channels.

Other primary conclusions of this document include:

- Approximately 2.3 Million bank cubic metres is available for use as closure cover from the Reclamation Overburden Dump.
- The cover thickness is proposed to have greater than 10% fines, and be placed at a minimum 0.5 m thickness. Based on current grading plans, this results in approximately 1,077,300 m^3 of cover material to be placed (in-situ thickness).
- Material meeting the cover specification was direct hauled from the Area 2 Stage 3 pit excavation and stockpiled at the Southwest Waste Dump, Main Waste Dump Expansion, Dry Stack Tailings Storage Facility, and Mill Valley Fill Extension.
- Revegetation seed mixes have been developed for sloped areas and level areas. These seed mixes have been purchased, and the seed is currently on-site.
- Facilities have been designed with re-graded slopes intended to provide a cut/fill balance while targeting overall slopes as shallow as possible.
- Facilities are to be graded to reduce the amount of water that flows over slopes. Facility tops are graded to central swales designed to accommodate a 1:200 year event, without the need for aggregate riprap, and that rely on vegetation to provide roughness within the channel.
- Additional work is required prior to finalizing the implementation of these cover designs.

This report, Updated Closure Cover Design for the Minto Mine 2018 Reclamation and Closure Plan, was prepared by

PROFESSIONAL ENGINEER
YUKON TERRITORY
ERIK P. KETILSON
Jan 30, 2018

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Date Feb 6, 2018
PERMIT NUMBER: PP019
Association of Professional Engineers of Yukon

and reviewed by

Dylan MacGregor, MASc, PGeo
Principal Consultant

All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

7 References

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Figures

REFERENCE

1. Ortohophoto date August 2017 and provided by Minto.
2. This figure should be read in conjunction with the Updated Closure Cover Design for the Minto Mine 2018 Reclamation and Closure Plan Report. Dated January 2018.

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SRK JOB NO.: 1CM002.049

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Minto Explorations Ltd.

2018 Updated Closure Cover Design

Existing Site Conditions

DATE: January 2018

APPROVED: EPK

FIGURE: 01

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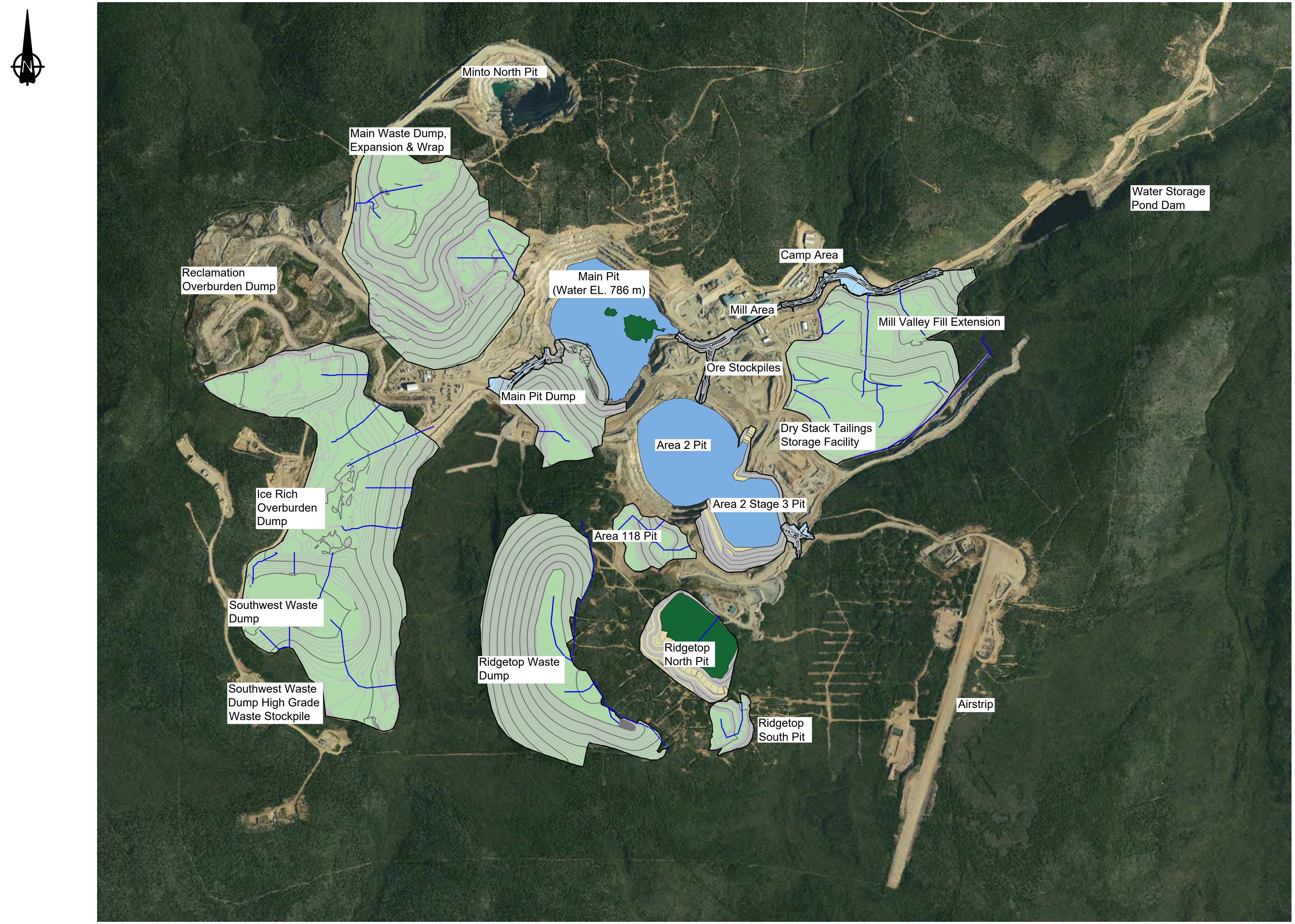
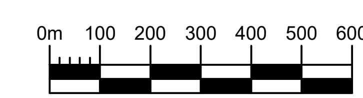


LEGEND

- Subaerial Tailings Cover (Detail 1, Figure 3)
- Cover Application Area (Detail 2, Figure 3)
- Open Pit Slopes
- Water
- Primary Water Conveyance Feature
- Secondary/Tertiary Water Conveyance Feature (Details 3 & 4, Figure 3)

REFERENCE

1. Contours shown as 2.0 m intervals
2. Ortohophoto date August 2017 and provided by Minto.
3. This figure should be read in conjunction with the Updated Closure Cover Design for the Minto Mine 2018 Reclamation and Closure Plan Report. Dated January 2018.



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2018 Updated Closure Cover Design

Final Closure Configuration

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FILE NAME:	1CM002.049_2018RCP-Regrade_R1.dwg

Minto Explorations Ltd.

DATE:	APPROVED:	FIGURE:
January 2018	EPK	02

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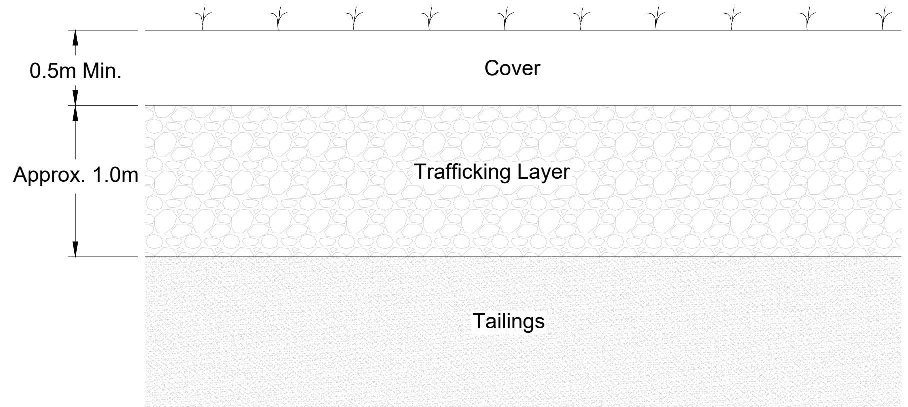

1 Subaerial Tailings Cover

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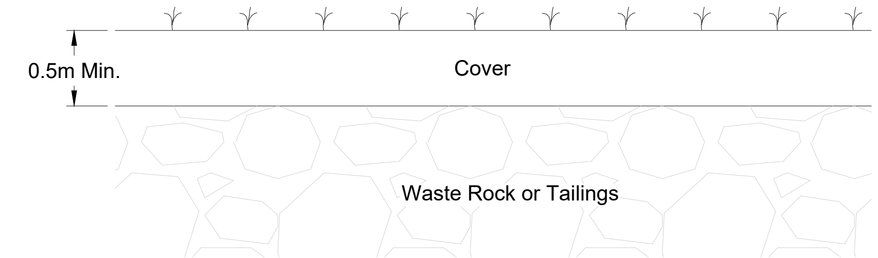
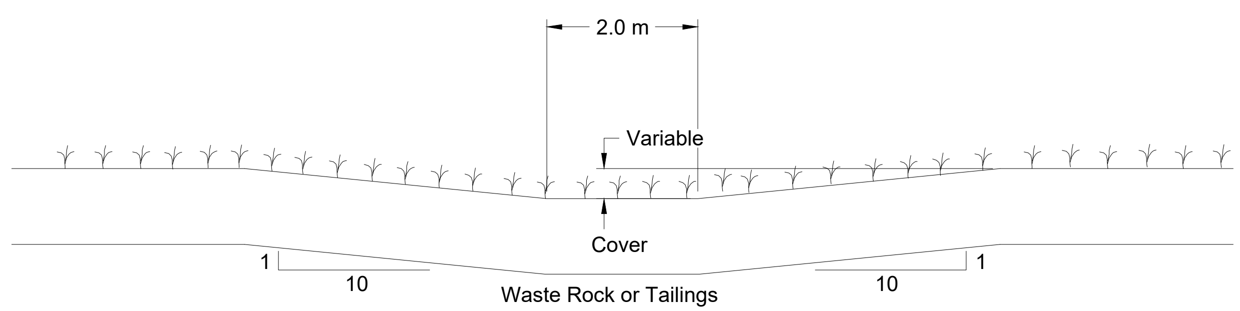


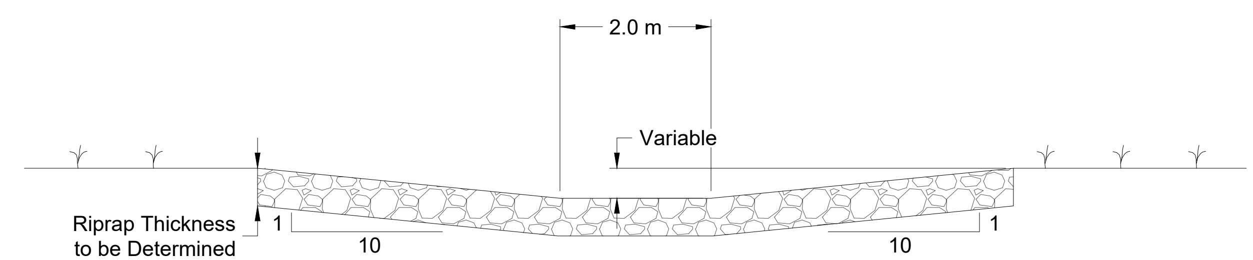
2 Cover Detail

Not To Scale



3 Swale Detail

Not To Scale



4 Slope Swale Detail

Not To Scale

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SRK JOB NO.: 1CM002.049	Minto Explorations Ltd.	Details
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Appendix A – Minto Closure Cover Design – Geotechnical Characteristics of the Cover Materials

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Memo

To:	File	**Client:**	Minto Exploration Ltd.
From:	Erik Ketilson, MEng, PEng.	**Project No:**	1CM002.049
Reviewed by:	Maritz Rykaart, PhD, PEng.	**Date:**	July 20, 2016
Subject:	Minto Closure Cover Design – Geotechnical Characterization of the Cover Materials		

1 Introduction

The Minto Mine requires closure covers to be placed over the waste rock and tailings facilities. The purpose of this memo is to characterize the overburden material to provide an appropriate material envelope to guide the construction of the cover material.

2 Cover Requirements

SRK completed numerical modelling to bracket percolation predictions in 2015 (SRK, 2015). The modelling indicated that without a cover, the net percolation could be between 39% and 45% and, depending on climactic conditions, could vary between 26% and 65%. Cover materials were applied, with the base case cover material consisting of material properties from sample MWD-TP4 collected at the Minto mine, which is a gravel and sand material with more than 25% fines (<0.075 microns). The results indicate that the net percolation is approximately 23%, but depending on the climactic conditions, can vary from 6% to 43%. The cover material was varied and an analysis was also completed considering a coarse material (MWD-TP3), which is predominantly gravel and sand with less than 10% fines (<0.075 microns). The results of this analysis indicated that the net percolation was approximately 23%, but depending on the climactic conditions, can vary from 5% to 44%.

The modelling results indicate that there is nearly a 20% decrease in net percolation after cover materials are included in the analysis. The cover thickness was assumed to be approximately 0.5 m thick, and following sensitivity analysis to the thickness (1 m and 2 m) minor decreases in net percolation were estimated. Therefore, a minimum cover thickness of 0.5 m was adopted for the project, with materials containing greater than 10% fines. Based on preliminary closure cover revegetation work completed by Integral Ecology Group (IEG) in 2016 (IEG, 2016), overburden materials containing greater than 10% fines are expected to support the growth of vegetation.

3 Geotechnical Material Characteristics

3.1 Particle Size Distribution

SRK evaluated 167 particle size distribution analyses completed on overburden samples at the Minto Site, and classified the particle size distribution based on the Modified Unified Soil Classification System (MUSCS) and the Unified Soil Classification System (USCS). Data was obtained from investigations completed, and documented by SRK (SRK, 2013, 2016a&b). By correlating the specific sample analysis with borehole location, SRK was able to classify the overburden by source location. Figure 1 illustrates the upper and lower bound of the particle size distributions for each area.

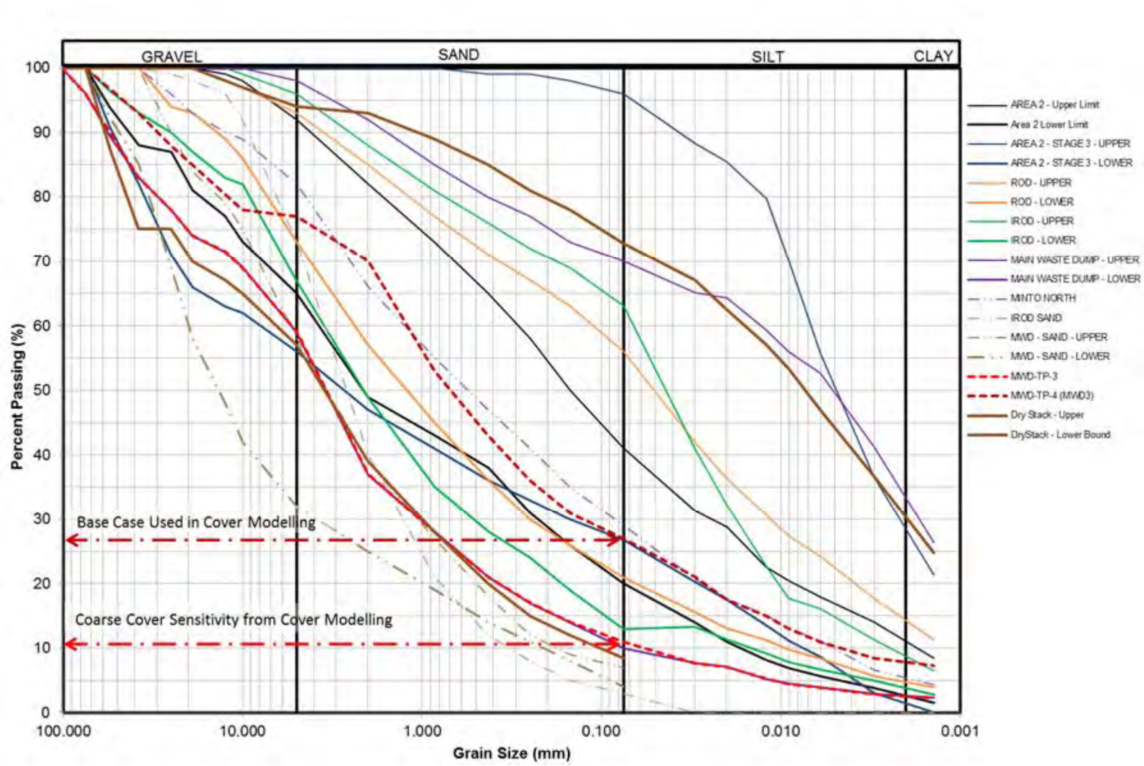

Figure 1: Particle Size Distribution

Source: Minto_MaterialProperties_1CM002-049_Rev00_EK.xlsx

The upper boundaries are also listed in tabular form in Table 1. The lower boundaries are listed in tabular form in Table 2.

Table 1: PSD Area Upper Bound

Upper Bound - Finer Limit					
Area	**Gravel**	**Sand**	**Fines**	**Silt**	**Clay**
Area 2	8	51	41	31	11
Area 2 - Stage 3	0	4	96	69	27
Drystack Tailings Cover	6	21	73	44	29
Ice Rich Overburden Dump	4	33	63	55	8
Main Waste Dump	2	28	70	38	32
Reclamation Overburden Dump	7	37	56	42	14

Source: Minto_MaterialProperties_1CM002-049_Rev00_EK.xlsx

Table 2: PSD Area Lower Bound

Lower Bound - Coarser Limit					
Area	**Gravel**	**Sand**	**Fines**	**Silt**	**Clay**
Area 2	35	45	20	18	2
Area 2 - Stage 3	44	29	27	26	1
Drystack Tailings Cover	43	49	9	2	6
Ice Rich Overburden Dump	33	54	13	9	4
Main Waste Dump	41	49	10	7	3
Reclamation Overburden Dump	27	52	21	16	5

Source: Minto_MaterialProperties_1CM002-049_Rev00_EK.xlsx

3.2 Atterberg Limits

Of the available samples, 38 had completed analysis to determine the Atterberg Limits (liquid and plastic limits). Data was obtained from investigations completed, and documented by SRK (SRK, 2013, 2016a&b). Figure 2 illustrates soil classification according to the modified unified soil classification system. The modified unified soil classification system is similar to the Unified Soil Classification System, however, splits low plastic clay classification into two categories including a clay of intermediate plasticity (CI).

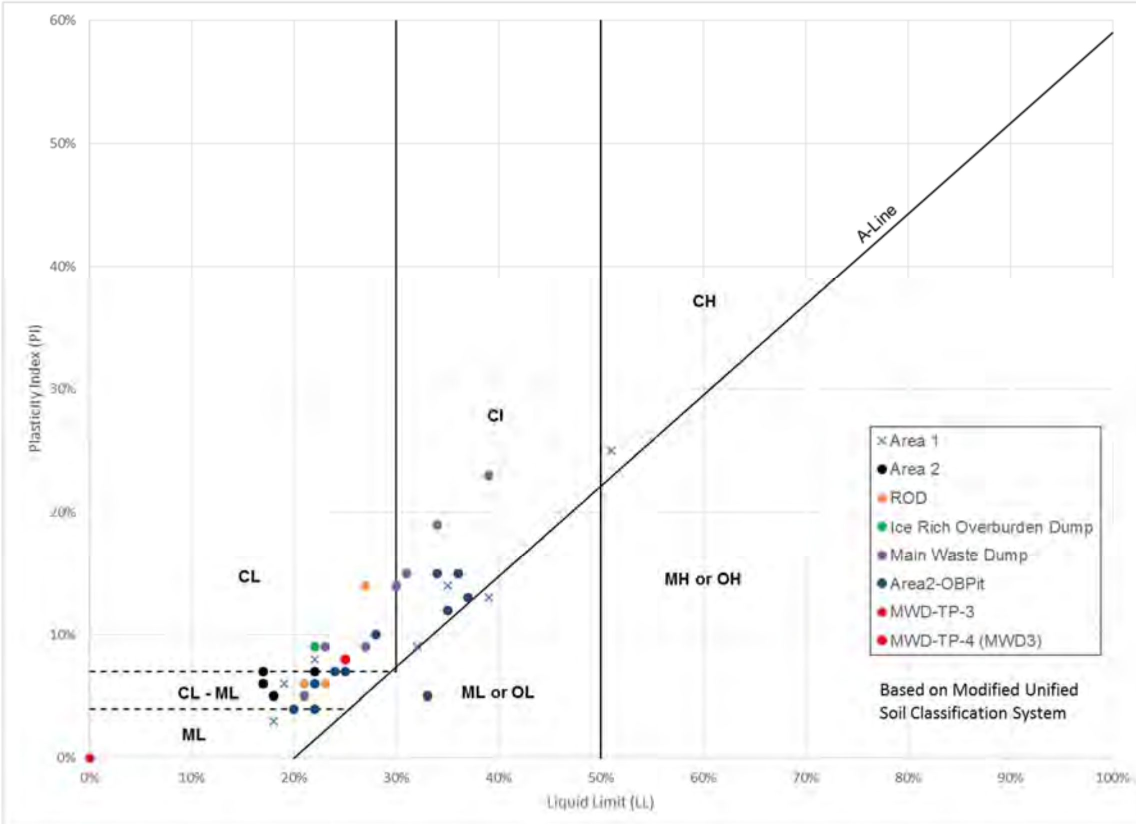

Figure 2: Atterberg Limits

Source: Minto_MaterialProperties_1CM002-049_Rev00_EK.xlsx

3.3 Strength

Strength characteristics for the site materials at Minto are provided within the review of geotechnical strength properties memorandum prepared by SRK (SRK, 2014).

3.4 Erosion

Soil erosion classification is based on the USDA soil textural classification. Table 3 provides a summary of the particle size diameter range based on the Unified soil classification system (USCS), and the United States Department of Agriculture (USDA) soil textural classification.

Table 3: USCS vs USDA Particle Size Distribution Systems

Soil Component	Particle Size Diameter Rage (millimeters)	
	USCS / MUSCS	**USDA**
Boulders	> 200	
Cobbles	200 – 76	
Gravel	76 – 4.75	
Sand	4.75 – 0.075	2.0 – 0.05
Silt	0.075 – 0.002	0.05 – 0.002
Clay	< 0.002	< 0.002

The samples were re-classified, and plotted on a soil texture triangle (Figure 3) to determine the general soil texture. The samples typically categorized as sandy loam.

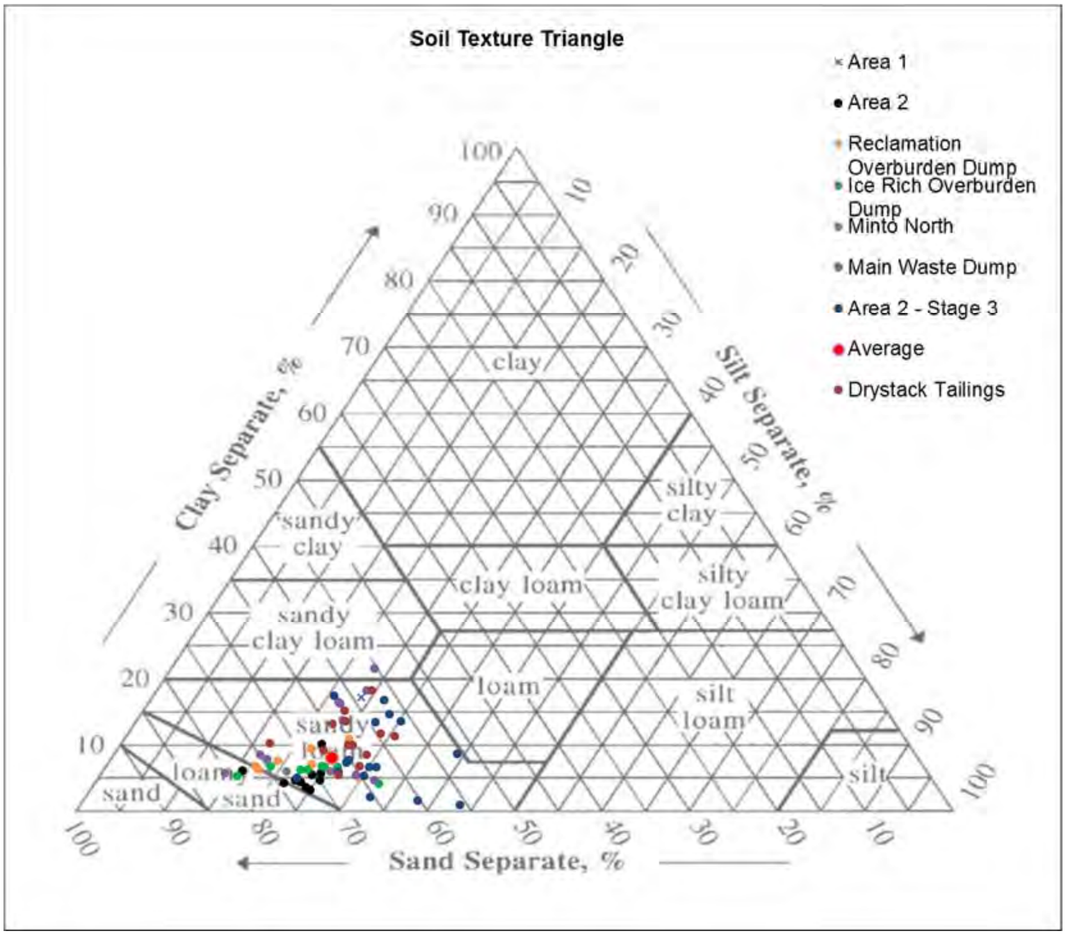

Figure 3: Soil Classification Based on Soil Texture Triangle

Source: Minto_MaterialProperties_1CM002-049_Rev00_EK.xlsx

4 Design Parameters

Based on the particle size distributions, and the net percolation cover modelling completed (SRK, 2015), Table 1 provides a summary of proposed design parameters to be adopted for the Minto Closure Covers.

Table 4: Closure Cover Design Parameters

<table>
<tr><th colspan="2">Description</th><th>Value</th></tr>
<tr><td colspan="2">Cover Thickness</td><td>0.5 m (minimum)</td></tr>
<tr><td rowspan="3">Cover Material Specifications</td><td>Gravel</td><td>0 % to 40%</td></tr>
<tr><td>Sand</td><td>60% to 90%</td></tr>
<tr><td>Fines</td><td>> 10%</td></tr>
<tr><td>Soil Texture Classification</td><td>Sandy Loam</td><td>Sandy Loam</td></tr>
</table>

5 References

(IEG, 2016). Minto Mine preliminary closure cover revegetation plan. Memorandum. Prepared for SRK Consulting (Canada) Inc. for the Minto Mine Site. Integral Ecology Group. July 29, 2016.

(SRK, 2013). 2012 Overburden Characterization Data Report for Minto Closure Covers. Report. Prepared for Minto Explorations Ltd. SRK Consulting (Canada) Inc. Project No. 1CM002.007. October 2013.

(SRK, 2014). Review of geotechnical strength properties at Minto Mine. Technical Memorandum. Prepared for Minto Explorations Ltd. SRK Consulting (Canada) Inc. Project No. 1CM002.018.110. July 17, 2014.

(SRK, 2015). Minto Mine Closure Covers: Results of Numerical Modelling to Bracket Percolation Predications. Technical Memorandum. Prepared for Minto Explorations Ltd. SRK Consulting (Canada) Inc. Project No. 1CM002.030. January 5, 2015.

(SRK, 2016a). Dry-stack Tailings Storage Facility Interim Cover Investigation. Technical Memorandum. Prepared for Minto Explorations Ltd. SRK Consulting (Canada) Inc. Project No. 1CM002.031.0500.03. April 7, 2016.

(SRK, 2016b). Minto Mine – 2014 and 2015 Area 2 Stage 3 Overburden Drilling. Technical Memorandum. SRK Consulting (Canada) Inc. Project No. 1CM002.037. July 2016.

Appendix B – Minto Mine – 2014 and 2015 Area 2 Stage 3 Overburden Drilling

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Memo

To:	File	**Client:**	Minto Explorations Ltd.
From:	Kaitlyn Kooy, EIT; Erik Ketilson, MEng, PEng	**Project No:**	1CM002.037
Reviewed by:	Maritz Rykaart, PhD, PEng	**Date:**	July 13, 2016
Subject:	Minto Mine - 2014 and 2015 Area 2 Stage 3 Overburden Drilling		

1 Introduction

The Minto Mine is a high-grade copper mine located in the Yukon, approximately 240 km north of Whitehorse. The mine site occupies the valley in the upper reaches of Minto Creek, a tributary on the west side of the Yukon River, about 9 km from the mouth. Operations are ongoing at this time (2016) and began in October 2007. Three pits have been completed to date: the Main Pit, the Area 118 Pit, and the Area 2 Stage 2 Pit.

In support of developing a more robust understanding of the resource within the proposed Stage 3 expansion of the Area 2 pit, Minto planned and executed a drilling program. This program provided an opportunity for Minto to evaluate if there may be minable units of cover material within the overburden that will be excavated as part of the pit development. SRK recommended that the Minto staff receive some basic training in soil logging to help identify possible soils that could be beneficial for closure purposes. SRK provided Minto with on-site staff training for soil logging of some boreholes completed in 2014 and 2015.

The memorandum provides a summary of SRK's assistance during the drilling program, interpretation of the material properties, and comments regarding the potential for mineable units of cover material within the identified overburden for boreholes completed under the supervision of SRK.

2 Field Visit

SRK's Murray McGregor, EIT, visited the Minto site from October 27th through November 5th 2014. During this time, Mr. McGregor was responsible for logging the overburden soils from the initial drill holes as well as training several site staff in basic soil logging methods. Soils were logged according to the Unified Soil Classification System and samples of each material unit were collected for laboratory testing (discussed in Section 4.0). Boreholes were advanced using an HQ diameter, diamond drill bit.

3 Borehole Locations

Table 1 provides a list of boreholes drilled during the 2014 and 2015 programs. The locations of the boreholes are provided in Figure 1. Borehole logs are provided in Attachment 1 and photos of the core form Attachment 2.

Table 1: 2014 – 2015 Drilling Program Boreholes

Hole ID	Easting(1)	Northing(1)	Drill Program
14-SWC-966	385107.8	6944363.1	Oct/Nov 2014
14-SWC-967	385146.1	6944317.3	Oct/Nov 2014
14-SWC-968	385169.1	6944289.2	Oct/Nov 2014
14-SWC-969	385172.2	6944225.0	Oct/Nov 2014
14-SWC-970	385125.3	6944272.0	Oct/Nov 2014
14-SWC-971	385075.1	6944288.0	Oct/Nov 2014
14-SWC-972	385215.6	6944284.0	Oct/Nov 2014
14-SWC-973	385164.4	6944349.0	Oct/Nov 2014
14-SWC-974	385140.0	6944379.0	Oct/Nov 2014
14-SWC-975	385156.1	6944428.0	Oct/Nov 2014
14-SWC-976	385075.3	6944328.0	Oct/Nov 2014
14-SWC-977	385097.9	6944254.0	Oct/Nov 2014
14-SWC-978	385122.4	6944219.0	Oct/Nov 2014
14-SWC-979	385218.8	6944233.0	Oct/Nov 2014
14-SWC-980	385194.5	6944261.0	Oct/Nov 2014
14-SWC-981	385148.0	6944188.0	Oct/Nov 2014
15-SWC-995	385096.1	6944251.6	Feb 2015
15-SWC-996	385161.0	6944314.9	Feb 2015
15-SWC-997	385140.9	6944124.0	Feb 2015

Notes:

(1) Easting and Northing presented in NAD 1983 UTM UTM Zone 8N

4 Soil Description

The encountered overburden materials within the Area 2, Stage 3 pit consists of layers with variable thickness of sand, gravel, silts, and clays. The borehole logs are included as Attachment 1, and photos of the core collected form Attachment 2.

An organic layer was noted only in one borehole – 14-SWC-979. The layer was identified between 0.7 m and 1.0 m below ground surface, and the layer was identified to contain primarily clay and silt sized particles with trace sand sized particles encountered. The soil was brown/black in colour, moist, and of medium plasticity.

Discontinuous layers of sand were identified in each of the boreholes. The sand was quite variable, and consisted of varying content of gravel, silt, and clay content and ranged from well to poorly graded, based on visual identification. The sand was generally brown, with varying shades of grey and red throughout. The sand was primarily identified as moist, with the exception of discreet layers in 14-SWC-968, 14-SWC-970, 14-SWC-971, 14-SWC-972, 14-SWC-973, 15-SWC-995, and 15-SWC-996 where the sand was identified as wet. In some cases, the sand was classified with low or medium plasticity – this was identified in boreholes 14-SWC-967, 14-SWC-969, 15-SWC-995, 15-SWC-996, and 15-SWC-997. The sand was otherwise identified as non-plastic. Generally, the sand unit was considered massive with the exception of 14-SWC-967; 15-SWC-997, and 15-SWC-997 where layers of sand were identified to be laminated or blocky.

Gravel layers were identified in boreholes 14-SWC-966; 14-SWC-967; 14-SWC-973; 14-SWC-975; 14-SWC-981; and 15-SWC-997. The gravel contained varying levels of sand, silt, and clay content. The material was generally brown, with varying shades or red and grey. The material was primarily identified as moist, with the exception of some layers in 15-SWC-997 which were identified as wet. The gravel layers were non-plastic, and massive.

Material classified as silt contained varying degrees of clay, sand, and gravel. The material was generally classified as poorly graded; however, layers were identified in 14-SWC-967, 14-SWC-972, 14-SWC-973, 15-SWC-995, 15-SWC-996, and 15-SWC-997. Generally, the silt was identified to be brown, with varying shades of grey. The moisture content was visually identified as primarily moist, with the exception of some layers identified in borehole 14-SWC-972, 14-SWC-974, 14-SWC-979, 15-SWC-995, and 15-SWC-996 as wet; and one layer from 28.6 m to 28.9 m in borehole 14-SWC-979 was identified as dry. The silt ranged from low to high plasticity. The material was generally classified as massive, with laminated layers identified in boreholes 14-SWC-969, 14-SWC-979, 15-SWC-996, and 15-SWC-997; and one layer was identified as blocky in each of boreholes 14-SWC-973 and 15-SWC-996.

Clay layers primarily contained silt with varying level of sand and gravel. The clay was generally poorly graded, and grey in colour, although some layers were identified as brown. The material was moist, with the exception of layers identified in 14-SWC-974 and 15-SWC-995 which were identified as wet. Clay samples were generally exhibited medium to high degrees of plasticity.

Bedrock was encountered at depths ranging between 3.15 m (14-SWC-966) to 26.5 m (14-SWC-973).

5 Laboratory Testing

During a subsequent site visit in February 2015, Mr. McGregor selected samples from the combined drilling of 2014 and 2015 programs to seek out continuous units of fine grained material containing clay which could be used in cover construction. Several samples were collected from boreholes beneath the Area 2 ring road. A summary of the laboratory tests performed are shown in Table 2.

Table 2: Laboratory Tests Performed

Hole ID	From (m)	To (m)	Sample ID	Moisture Content	Particle Size Analysis	Atterberg Limits
14-SWC-968	15.05	15.40	MM-101259	✓	✓	✓
14-SWC-970	5.65	6.00	MM-101262	✓	✓	✓
14-SWC-969	12.00	12.30	MM-101270	✓	✓	
	19.05	19.35	MM-101273	✓	✓	
14-SWC-972	9.25	9.55	MM-101277	✓	✓	✓
	18.55	18.85	MM-101280	✓	✓	
14-SWC-973	2.80	3.10	MM-101285	✓	✓	✓
	9.17	9.47	MM-101288	✓	✓	✓
14-SWC-975	5.70	6.00	MM-101298	✓	✓	✓
14-SWC-979	20.60	20.90	MM-101317	✓	✓	✓
14-SWC-980	19.40	19.70	MM-101326	✓	✓	✓
15-SWC-995	8.60	8.90	58554	✓	✓	
15-SWC-996	6.12	6.42	58557	✓	✓	✓
	10.69	11.00	58558	✓		
	14.73	15.10	58559	✓	✓	✓
15-SWC-997	9.79	10.11	160025	✓	✓	✓
	15.64	15.88	58565	✓		
	23.09	23.43	58568	✓	✓	✓
	30.60	30.91	58570	✓		
	41.32	41.67	58572	✓	✓	✓

5.1 Test Results

The test results are presented in Attachment 3. Natural moisture content analysis results are summarized in Table 3. Particle size distribution analysis is illustrated in Figure 1, while results of the Atterberg Limits, as classified using the Modified Unified Soil Classification System (MUSCS), is illustrated in Figure 2.

Table 3: Natural Moisture Content Analysis Results

Hole ID	From (m)	To (m)	Moisture Content
14-SWC-968	15.05	15.40	16.6%
14-SWC-970	5.65	6.00	27.6%
14-SWC-969	12.00	12.30	10.7%
	19.05	19.35	26.3%
14-SWC-972	9.25	9.55	16.6%
	18.55	18.85	31.7%
14-SWC-973	2.80	3.10	35.9%
	9.17	9.47	13.2%
14-SWC-975	5.70	6.00	28.1%
14-SWC-979	20.60	20.90	26.5%
14-SWC-980	19.40	19.70	18.8%
15-SWC-995	8.60	8.90	13.4%
15-SWC-996	6.12	6.42	14.8%
	10.69	11.00	21.7%
	14.73	15.10	16.1%
15-SWC-997	9.79	10.11	10.3%
	15.64	15.88	13.7%
	23.09	23.43	11.7%
	30.60	30.91	15.4%
	41.32	41.67	12.7%

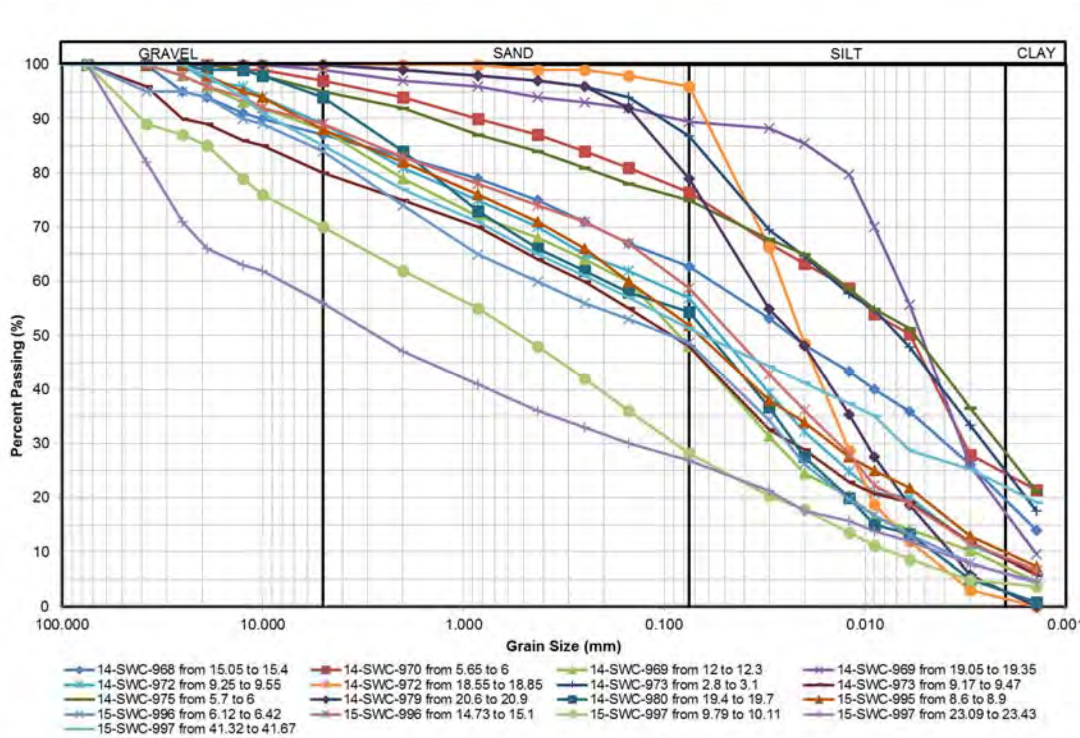


Figure 1: Particle Size Distribution Analysis Results

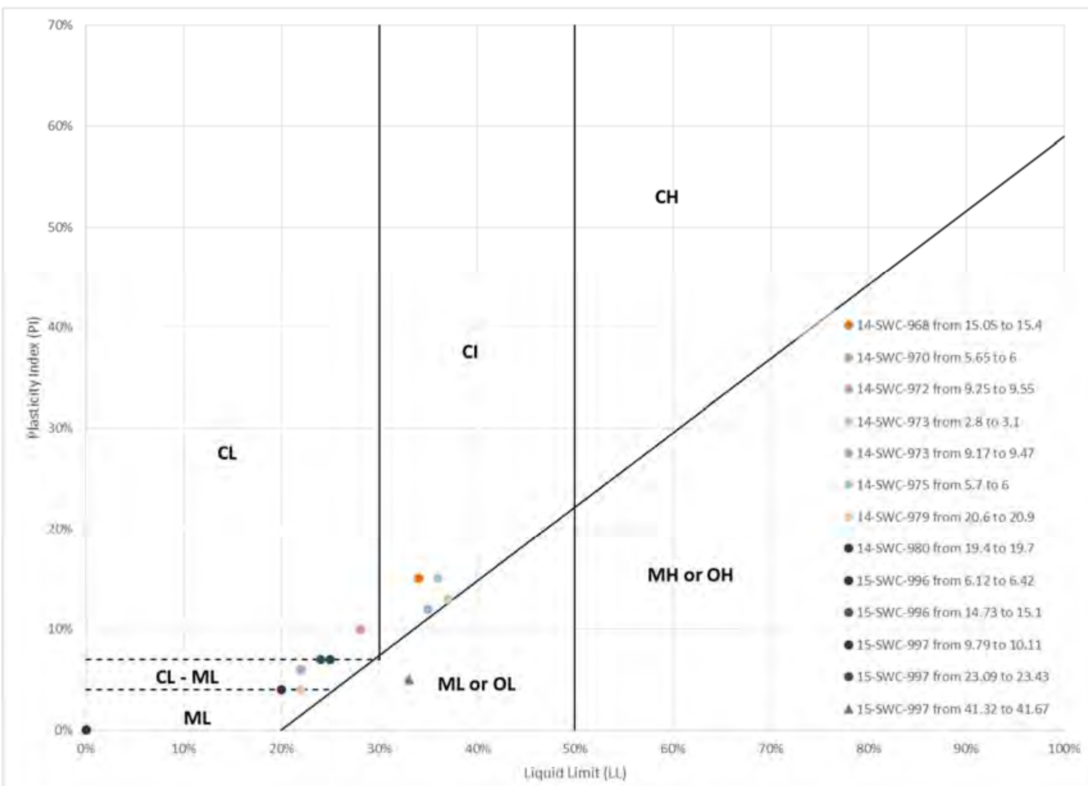


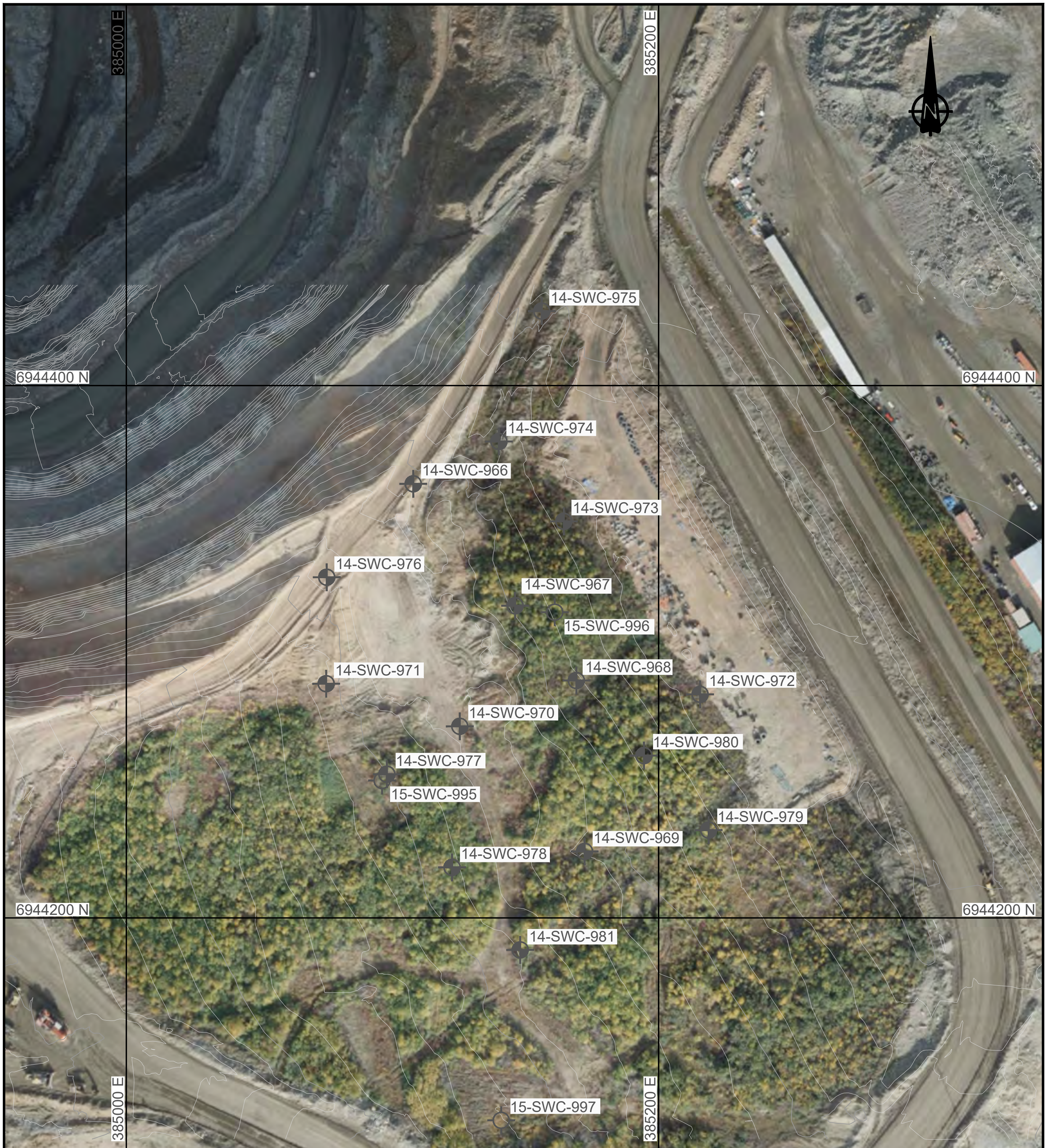
Figure 2: Atterberg Limit Analysis Results

6 Conclusions

Based on review of the borehole logs, and laboratory testing results, the data suggests that the overburden material encountered is not present in appropriate continuity to facilitate effective selection and segregation of materials using mass mining methods.

Testing indicates that the natural moisture content ranges between 10% and 36%. Particle size distributions analysis indicated fines content ranging between 26% and 96%; with clay sized particles ranging between <1% to approximately 30%. Atterberg limit analysis indicated that the sample classification was variable, including intermediate plasticity clays, and low plasticity clays and/or silts.

Figure



LEGEND

Oct./Nov. 2014 Drill Program

Feb. 2015 Drill Program

NOTES

1. Data presented in NAD83 UTM Zone 8N.
2. Orthophoto provided by Minto Mine, 2014.

0 20 40 60 80 100

Scale in Metres

srk consulting

capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.

Area 2 Stage 3 Overburden Drilling

Area 2 Stage 3 2014/2015 Overburden Drilling Locations

SRK JOB NO.: 1CM002.037

FILE NAME: OVB_Drilling_Borehole_Plan_1CM002_037.dwg

Minto Mine

DATE: July 2016 | APPROVED: KNK | FIGURE: 1

Z:\01_SITES\Minto\1040_AutoCAD\OVB Drilling 2014-15\OVB_Drilling_Borehole_Plan_1CM002_037.dwg

Attachment 1: Borehole Logs

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Capstone MINTO MINE

HOLE ID:	**14-SWC-966**	COORDINATES:	385107.8 E 6944363.1 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	830.7
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	827.05
LOGGED BY:	MJM	TOTAL DEPTH (m):	3.65
BORING DATE:	Oct/Nov 2014	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol

Organics, Clay, Silt, Sand, Gravel, Boulder, Bedrock, Cobbles

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Recovery %	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
0	830.6		MM-1012 51	Sand	SAND, few gravel, well graded, light brown, sub-angular, moist, non-plastic, non-cohesive, massive	
				Boulder	BOULDER	Granoriorite
				Sand	SAND, few gravel, well graded, light brown, sub-angular, moist, non-plastic, non-cohesive, massive	
2	828.6		MM-1012 52	Gravel	GRAVEL, some sand , well graded, light brown, sub-angular, moist, non-plastic, non-cohesive, massive	Minor fines near bedrock transition
				Bedrock	BEDROCK	Weathered granodiorite
4						

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Capstone MINTO MINE

HOLE ID:	14-SWC-967	COORDINATES:	385146.1 E 6944317.3 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	828.4
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	814.4
LOGGED BY:	MJM	TOTAL DEPTH (m):	14
BORING DATE:	Oct/Nov 2014	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Legend: Moisture Content, Liquid Limit, Plastic Limit (%)

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Sample	Soil Description	Drilling Notes & Additional Comments
0 – 0.25		SILT, some sand , little gravel, well graded, black, sub-angular, moist, non-plastic, cohesive, massive	Unclear how much organics exist due to poor recovery
0.25 – 4.05	MM-1012 53	CLAY, some silt, few sand , few gravel, well graded, grey-brown, sub-rounded, moist, low-plasticity, cohesive, massive	Matrix supported
			Decreased gravel content
4.05 – 7.5	MM-1012 54	SAND, some silt, trace gravel, poorly graded, grey-brown, sub-rounded, moist, low-plasticity, cohesive, laminated	Sand fraction is primarily fine
7.5 – 10.7	MM-1012 55	GRAVEL, few sand , few silt, well graded, brown, sub-angular, moist, low-plasticity, cohesive, massive	Poor recovery from 9m to 10.5m; likely the same material unit with fines washed out
10.7 – 14	MM-1012 56	SAND, little gravel, well graded, light brown, sub-angular, moist, non-plastic, non-cohesive, massive	Primarily medium to coarse sand

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Capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID:	14-SWC-967	COORDINATES:	385146.1 E 6944317.3 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	828.4
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	814.4
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	14

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Clay, Silt, Sand, Gravel, Boulder, Bedrock, Cobbles

Moisture Content, Liquid Limit, Plastic Limit (%): 0, 20, 40, 60, 80, 100

PSD: Gravel / Sand / Silt / Clay(%)

Sample Type: Grab, SPT

Recovery %: 0, 20, 40, 60, 80, 100

Depth (m)	Elev (m)	USCS	Soil Description	Drilling Notes & Additional Comments
			BEDROCK	Weathered granodiorite
14				

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Capstone MINTO MINE

HOLE ID:	**14-SWC-968**	COORDINATES:	385169.1 E 6944289.2 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	827.7
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	807.7
LOGGED BY:	MJM	TOTAL DEPTH (m):	20
BORING DATE:	Oct/Nov 2014	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol

Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Moisture Content

Liquid Limit

Plastic Limit

(%) 0 20 40 60 80 100

PSD Gravel / Sand / Silt / Clay(%)

Depth (m) | Elev (m) | Recovery % 0 20 40 60 80 100 | **Sample Type** Grab, SPT | **USCS** | **Soil Description** | **Drilling Notes & Additional Comments**

Depth (m)	Elev (m)	Sample	Soil Description	Drilling Notes & Additional Comments
0			SAND, few silt, little gravel, well graded, grey-brown, moist, non-plastic, cohesive, massive	Extremely poor recovery in first four runs assumed to be the same material type as observed in run starting at 6m; some matrix
	827			
2				
	825			
4				
	823			
6				
	821			
8		MM-1012 57		
	819			
10				
	817			
12			SAND, some silt, trace gravel, poorly graded, brown, wet, cohesive, massive	
	815	MM-1012		

srk consulting

capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID:	**14-SWC-968**	COORDINATES:	385169.1 E 6944289.2 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	827.7
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	807.7
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	20

DEPOSIT AREA: Area 2

Lithological Symbol

Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: 🟥 Grab 🟩 SPT

● Moisture Content ◆ Liquid Limit ● Plastic Limit (%) 0 20 40 60 80 100

PSD Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Recovery % 0 20 40 60 80 100	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
			MM-1012 58			
14	813		MM-1012 59		SILT, some clay, few sand , little gravel, poorly graded, grey-brown, sub-angular, moist, low-plasticity, cohesive, massive	
16	811				SAND, some gravel, well graded, light brown, sub-angular, moist, non-plastic, non-cohesive, massive	Primarily medium to coarse sand
18	809		MM-1012 60			
					BEDROCK	Extreme weathering to 32m
20						

13/24/44/1 9

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Capstone MINTO MINE

HOLE ID:	**14-SWC-969**	COORDINATES:	385172.2 E 6944225 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	831.1
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	808.1
LOGGED BY:	MJM	TOTAL DEPTH (m):	23
BORING DATE:	Oct/Nov 2014	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol: Organics, Clay, Silt, Sand, Gravel, Boulder, Bedrock, Cobbles

Sample Type: Grab, SPT

Legend: Moisture Content, Liquid Limit, Plastic Limit (%)

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments	PSD
0	831.1			SAND, few gravel, little silt, well graded, light brown, sub-rounded, moist, non-plastic, non-cohesive, massive	Majority of matrix material (sand) washed out	
6				SAND, some clay and silt, little gravel, poorly graded, dark brown, sub-angular, moist, low-plasticity, cohesive, massive		
7.5		MM-1012 68 (Grab)		SILT, some clay, little gravel, poorly graded, dark grey, sub-angular, moist, mid-plasticity, cohesive, laminated	Trace sand	
9		MM-1012 69 (Grab)		SAND, some gravel, little clay and silt, well graded, grey brown, sub-angular, moist, non-plastic, cohesive, massive	Occasional cobbles	
10.7		MM-1012 70 (Grab)		SAND, few clay and silt, little gravel, well graded, brown grey, sub-angular, moist, low-plasticity, cohesive, massive	Variable concentrations of silt and silt with clay; coarse brown sand layer at 11.05-11.3m	12/40/41/7
12.5				SAND, some clay, few silt, poorly graded, dark grey, sub-angular, moist, mid-plasticity, cohesive, massive	Minor organic intervals of <3cm	

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capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID:	**14-SWC-969**	COORDINATES:	385172.2 E 6944225 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	831.1
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	808.1
LOGGED BY:	MJM	TOTAL DEPTH (m):	23
BORING DATE:	Oct/Nov 2014	DEPOSIT AREA:	Area 2

Lithological Symbol

Organics · Sand · Bedrock · Clay · Gravel · Cobbles · Silt · Boulder

■ Moisture Content ♦ Liquid Limit ● Plastic Limit (%) 0 20 40 60 80 100

PSD Gravel / Sand / Silt / Clay(%)

Depth (m) · Elev (m) · Recovery % (0 20 40 60 80 100) · Sample Type (🟥 Grab, 🟩 SPT) · **USCS** · **Soil Description** · **Drilling Notes & Additional Comments**

Depth: 14, 16, 18, 20, 22, 24

Elev: 818, 816, 814, 812, 810, 808, 806

Samples: MM-1012 71; MM-1012 72; MM-1012 73; MM-1012 74

Soil Description	Drilling Notes & Additional Comments
SAND, few gravel, few clay and silt, well graded, grey, sub-angular, moist, low-plasticity, cohesive, massive	Occasional cobbles
SAND, few gravel, few silt, well graded, brown grey and reddish grey, sub-angular, moist, non-plastic, cohesive, massive	Minor low-plasticity intervals
SILT, some sand , little gravel, poorly graded, grey brown, sub-angular, moist, non-plastic, cohesive, massive	
SAND, few silt, little gravel, well graded, reddish grey brown, sub-angular, moist, non-plastic, cohesive, massive	Contact with bedrock
BEDROCK	Extremely weathered to 23.0m, heavily weathered to 29.50 m

PSD: 1/10/74/15

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Capstone MINTO MINE

HOLE ID:	**14-SWC-970**	COORDINATES:	385125.3 E 6944272 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	835.1
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	820.75
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	14.35

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%): 0, 20, 40, 60, 80, 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample	USCS	Soil Description	Drilling Notes & Additional Comments	PSD
0			Sand	SAND, some gravel, little silt, well graded, grey-brown, sub-rounded, moist, non-plastic, cohesive, massive	Occasional organic lenses to 8m	
	834	MM-1012 61				
2	832					
4	830					
		MM-1012 62	Silt	SILT, some clay, few sand , trace gravel, poorly graded, grey-brown, sub-rounded, moist, mid-plasticity, cohesive, massive		3/21/52/24
6	828					
8	826				Increased sand content, reduced plasticity	
		MM-1012 63				
10			Sand	SAND, some silt, little gravel, well graded, grey-brown, sub-rounded, moist, non-plastic, cohesive, massive		
	824	MM-1012 64				
12		MM-1012 65	Sand	SAND, little gravel, well graded, light brown, sub-angular, wet, non-plastic,		

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Capstone MINTO MINE

PROJECT: Minto
CLIENT: Minto Exploration Ltd.

HOLE ID: 14-SWC-970
LOCATION: Yukon
PROJECT NO: 1CM002.037
DRILLING CONTRACTOR: Driftwood
DRILLING TYPE & CORE DIA: HQ Diamond
LOGGED BY: MJM
BORING DATE: Oct/Nov 2014

COORDINATES: 385125.3 E 6944272 N
DATUM: UTM Zone 8
GROUND ELEV (m): 835.1
AZIMUTH: 0
COLLAR DIP: -90
EOH ELEV. (m): 820.75
TOTAL DEPTH (m): 14.35
DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Clay, Silt, Sand, Gravel, Boulder, Bedrock, Cobbles

Sample Type: Grab, SPT

Legend: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Recovery %	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
	822			Sand	non-cohesive, massive	
14				Bedrock	BEDROCK	Heavily weathered to 14.35m

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Capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID:	**14-SWC-971**	COORDINATES:	385075.1 E 6944288 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	840.5
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	836.4
LOGGED BY:	MJM	TOTAL DEPTH (m):	4.1
BORING DATE:	Oct/Nov 2014		

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Clay, Silt, Sand, Gravel, Boulder, Bedrock, Cobbles

Sample Type: Grab, SPT

Legend: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
0			Sand	SAND, few gravel, little silt, well graded, dark red-brown, sub-angular, wet, non-plastic, non-cohesive, massive	Occasional organics within fine sand lenses; No sample due to mixing of polymer into core
	839.6				
2			Clay	CLAY, little sand , trace gravel, poorly graded, grey, moist, mid-plasticity, cohesive, massive	
		MM-1012 66			
	837.6				
		MM-1012 67	Sand	SAND, little gravel, well graded, light brown, sub-angular, wet, non-plastic, non-cohesive, massive	
4			Bedrock	BEDROCK	Extremely weathered to 4.5m; heavily weathered to 5.1m

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Capstone MINTO MINE

HOLE ID:	**14-SWC-972**	COORDINATES:	385215.6 E 6944284 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	822.4
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	797.1
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	25.3

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%)

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Recovery %	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
0	822		MM-1012 75		SAND , few gravel, some silt, well graded, Brownish Grey, sub-angular, moist, non-plastic, cohesive, massive	
			MM-1012 76		SILT, some clay, few gravel, little sand , well graded, Grey, angular, moist, low-plasticity, cohesive, massive	
			MM-1012 77		SILT, some clay, little gravel, some sand , well graded, Grey, sub-angular, moist, low-plasticity, cohesive, massive	PSD: 11/32/49/8
			MM-1012 78		SILT, some sand , trace gravel, well graded, Brown grey, sub-angular, wet, non-plastic, non-cohesive, massive	Chunk of cobble, and 3 sections of organic material 10 cm thick
	810				SAND, few silt, little clay, well graded, brown/grey, sub-rounded, moist, non-plastic, non-cohesive, massive	

Depth scale: 0, 2, 4, 6, 8, 10, 12. Elevation scale: 822, 820, 818, 816, 814, 812, 810.

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capstone MINTO MINE

HOLE ID:	**14-SWC-972**	COORDINATES:	385215.6 E 6944284 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	822.4
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	797.1
LOGGED BY:	MJM	TOTAL DEPTH (m):	25.3
BORING DATE:	Oct/Nov 2014	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Legend: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Sample Type: Grab, SPT

Depth (m): 14, 16, 18, 20, 22, 24, 26

Elev (m): 808, 806, 804, 802, 800, 798

Samples: MM-1012 79; MM-1012 80; MM-1012 81; MM-1012 82; MM-1012 83

USCS	Soil Description	Drilling Notes & Additional Comments
Sand		
Silt	SILT, few sand , poorly graded, brown, wet, non-plastic, cohesive, massive	
Sand	SAND, little silt, poorly graded, brown, wet, non-plastic, non-cohesive, massive	Primarily fine sand
Sand	SAND, few silt, few gravel, well graded, brown, wet, non-plastic, cohesive, massive	Increased gravel content in bottom of this material unit
Sand	SAND, some gravel, well graded, light brown, wet, non-plastic, non-cohesive, massive	
Bedrock	BEDROCK	Heavily weathered to 28m

PSD (sample MM-1012 80): 0/4/95/1

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Capstone MINTO MINE

HOLE ID:	**14-SWC-973**
LOCATION:	Yukon
PROJECT NO:	1CM002.037
DRILLING CONTRACTOR:	Driftwood
DRILLING TYPE & CORE DIA:	HQ Diamond
LOGGED BY:	MJM
BORING DATE:	Oct/Nov 2014

COORDINATES:	385164.4 E 6944349 N
DATUM:	UTM Zone 8
GROUND ELEV (m):	824
AZIMUTH:	0
COLLAR DIP:	-90
EOH ELEV. (m):	797
TOTAL DEPTH (m):	27

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Clay, Silt, Sand, Gravel, Boulder, Bedrock, Cobbles

Moisture Content; Liquid Limit; Plastic Limit; (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m) | Elev (m) | Recovery % (0 20 40 60 80 100) | Sample Type (Grab, SPT)

Depth (m)	Elev (m)	Sample	USCS	Soil Description	Drilling Notes & Additional Comments	PSD
0	824	MM-1012 84	Silt	SILT, some clay, few gravel, poorly graded, grey/broun, sub-rounded, moist, mid-plasticity, cohesive, massive	Hole 14-SWC-973 has occasional ice lenses <2cm thick to 5m depth; approx. 5% excess ice; occasional cobbles; actual length of	
2	822	MM-1012 85	Clay	CLAY, trace silt, trace gravel, poorly graded, Grey, sub-angular, moist, high-plasticity, cohesive, massive	Actual length of core 1.34m	0/13/63/24
4	820	MM-1012 86	Silt	Silt, some clay, some sand , little organics, well graded, grey/brown, moist, low-plasticity, cohesive, massive	Actual length of core 2.06m	
6	818	MM-1012 87	Sand	SAND, some clay and silt, little gravel, well graded, brown/grey, sub-rounded, wet, non-plastic, non-cohesive, massive	Actual length of core 1.72m	
8	816	MM-1012 88	Silt	SILT, some clay, few gravel, trace sand , well graded, grey/brown, sub-angular, moist, mid-plasticity, cohesive, blocky	Actual length same as run block	20/32/40/8
10	814					
12	812	MM-1012 89	Gravel	GRAVEL, few sand , trace clay and silt, poorly graded, reddisg brown, sub-angular, moist, non-plastic, non-cohesive		

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Capstone MINTO MINE

HOLE ID:	**14-SWC-973**	COORDINATES:	385164.4 E 6944349 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	824
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	797
LOGGED BY:	MJM	TOTAL DEPTH (m):	27
BORING DATE:	Oct/Nov 2014	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Legend: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Recovery %	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
				Gravel	GRAVEL, little sand , poorly graded, grey/black brown, angular, moist, non-plastic, non-cohesive	No sample
14	810					
				Gravel	GRAVEL, some sand , trace silt, well graded, brown, angular, moist, non-plastic, non-cohesive, massive	One sample from box
16	808					
18	806					
20	804					
22	802		MM-1012 90 (Grab)			
				Gravel	GRAVEL, few sand , trace silt, poorly graded, brown, angular, moist, non-plastic, non-cohesive, massive	
24	800					
			MM-1012 91 (Grab)			
26	798					

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Capstone MINTO MINE

HOLE ID:	14-SWC-973	COORDINATES:	385164.4 E 6944349 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	824
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	797
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	27

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Clay, Silt, Sand, Gravel, Boulder, Bedrock, Cobbles

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Recovery %	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
26	798			Gravel		
				Bedrock	BEDROCK	Rock to 29.5m; no sample
28	796					

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Capstone MINTO MINE

HOLE ID:	14-SWC-974	COORDINATES:	385140 E 6944379 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	824.8
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	811.3
LOGGED BY:	MJM	TOTAL DEPTH (m):	13.5
BORING DATE:	Oct/Nov 2014	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol: Organics, Clay, Silt, Sand, Gravel, Boulder, Bedrock, Cobbles

Sample Type: Grab, SPT

Moisture Content; Liquid Limit; Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Sample	USCS	Soil Description	Drilling Notes & Additional Comments
MM-1012 92		SILT, little organics, little sand , poorly graded, grey, sub-rounded, wet, low-plasticity, cohesive, massive	Actual length of core 1.5m
MM-1012 93		CLAY, few silt, trace sand , poorly graded, grey, sub-rounded, wet, low-plasticity, cohesive, massive	
MM-1012 94		CLAY, little silt, trace sand , poorly graded, grey/brown, angular, moist, mid-plasticity, cohesive, massive	Actual length of core 2.5m
MM-1012 95		CLAY AND SILT, trace sand , little gravel, poorly graded, grey, sub-rounded, moist, mid-plasticity, cohesive, massive	Actual length of core 2.1m
MM-1012 96		BEDROCK, few gravel, little sand , poorly graded, red/brown, angular, moist, non-plastic, non-cohesive, massive	Actual length of core 4.5m
		BEDROCK, little gravel, trace sand , poorly graded, red/brown, angular, moist, non-plastic, non-cohesive, massive	Tagging error: 12.5 to 13.5. Actual length of core = 2.75m

Depth (m): 0, 2, 4, 6, 8, 10, 12

Elev (m): 824, 822, 820, 818, 816, 814, 812

Recovery %: 0 20 40 60 80 100

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Capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID:	**14-SWC-974**	COORDINATES:	385140 E 6944379 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	824.8
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	811.3
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	13.5

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content; Liquid Limit; Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Recovery % (0 20 40 60 80 100)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
				Bedrock		
14						

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Capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID:	**14-SWC-975**	COORDINATES:	385156.1 E 6944428 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	818.7
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	796.3
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	22.4

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content; Liquid Limit; Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments	PSD
0	818.7	MM-101297 (Grab)	Clay	CLAY AND SILT, little sand , little gravel, poorly graded, grey/brown, sub-angular, moist, mid-plasticity, cohesive, massive	Top 1.1 m missing; only 20cm of 1.5m to 3m present (run tag reads "wash"); actual length of core = 1.18m	
		MM-101298 (Grab)	Clay	CLAY, little silt, trace gravel, poorly graded, grey, sub-angular, moist, high-plasticity, cohesive, massive		5/20/48/27
		MM-101299 (Grab)	Clay	CLAY, some gravel, little sand , poorly graded, grey, sub-rounded, moist, low-plasticity, cohesive, massive		
		MM-101300 (Grab)	Gravel	GRAVEL, few clay and silt, trace sand , poorly graded, grey/brown, sub-rounded, moist, non-plastic, non-cohesive, massive	Some cobbles	
			Sand	SAND, little silt, trace clay, poorly graded, brown, sub-angular, moist, non-plastic, cohesive, massive		

Depth scale (m): 0, 2, 4, 6, 8, 10, 12

Elevation scale (m): 818, 816, 814, 812, 810, 808, 806

Recovery %: 0 20 40 60 80 100

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Capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID:	**14-SWC-975**	COORDINATES:	385156.1 E 6944428 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	818.7
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	796.3
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	22.4

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Moisture Content; Liquid Limit; Plastic Limit (%) 0 20 40 60 80 100

PSD Gravel / Sand / Silt / Clay(%)

Sample Type: Grab, SPT

Depth (m)	Elev (m)	Sample	USCS	Soil Description	Drilling Notes & Additional Comments
~13.2		MM-1013 01	Sand		
~15.1		MM-1013 02	Sand		
~16.7	~802		Gravel	GRAVEL, some sand , trace silt, poorly graded, brown, angular, moist, non-plastic, non-cohesive, massive	Sections of competent and weathered rock
~20.5		MM-1013 03	Gravel		
22.4	796.3				

Depth scale: 14, 16, 18, 20, 22, 24. Elevation scale: 804, 802, 800, 798, 796, 794. Recovery %: 0 20 40 60 80 100

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Capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID:	14-SWC-976	COORDINATES:	385075.3 E 6944328 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	837.5
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	832.77
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	4.8

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
0 – 2.8	837.2, 835.2	MM-101304 (Grab)	Sand	SAND, little silt, trace gravel, poorly graded, brown, sub-rounded, moist, non-plastic, non-cohesive, massive	Sections of competent and weathered rock
2.8 – 4.5	833.2	MM-101305 (Grab)	Sand	SAND, trace silt, poorly graded, light brown, sub-angular, moist, non-plastic, non-cohesive, massive	
4.5 – 4.8		MM-101306 (Grab)	Sand	SAND, trace clay and silt, poorly graded, brown, sub-angular, moist, non-plastic, non-cohesive, massive	Sections of competent and weathered rock

Depth scale: 0, 2, 4, 6. Recovery %: 0 20 40 60 80 100

HOLE ID:	**14-SWC-977**	COORDINATES:	385097.9 E 6944254 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	839.4
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	827.3
LOGGED BY:	MJM	TOTAL DEPTH (m):	12.1
BORING DATE:	Oct/Nov 2014		

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%): 0, 20, 40, 60, 80, 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
0			Silt	SILT, some clay, few sand , trace gravel, poorly graded, grey brown, sub-angular, moist, mid-plasticity, cohesive, massive	Long interval of ablation till
	839				
2					
	837				
4					
	835	MM-1013 07			
6					
	833				
8					
	831	MM-1013 08			
10					
	829				
			Sand	SAND, few clay and silt, poorly graded, reddish grey brown, sub-rounded, moist, non-plastic, non-cohesive, massive	
		MM-1013 09			
12					
	827				

HOLE ID:	14-SWC-977	COORDINATES:	385097.9 E 6944254 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	839.4
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	827.3
LOGGED BY:	MJM	TOTAL DEPTH (m):	12.1
BORING DATE:	Oct/Nov 2014	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol

Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Moisture Content

Liquid Limit

Plastic Limit

PSD

Depth (m)	Elev (m)	Recovery % (0 20 40 60 80 100)	Sample Type (Grab / SPT)	USCS	Soil Description	Drilling Notes & Additional Comments	(%) 0 20 40 60 80 100	Gravel / Sand / Silt / Clay(%)
14								

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HOLE ID:	**14-SWC-978**	COORDINATES:	385122.4 E 6944219 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	837.2
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	825.9
LOGGED BY:	MJM	TOTAL DEPTH (m):	11.3
BORING DATE:	Oct/Nov 2014		

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Moisture Content; Liquid Limit; Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Sample Type: Grab; SPT

Recovery % 0 20 40 60 80 100

Depth (m)	Elev (m)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
0	837				
2	835				
4	833				
6	831				
		MM-1013 10 (Grab)	Clay	CLAY AND SILT, some sand , little gravel, poorly graded, brown matrix, sub-angular, moist, mid-plasticity, cohesive, massive	Diamictic ablational till, frequent granitic cobble, contact sharp in washout zone with underlying granodioritic regolith
8	829				
10	827	MM-1013 11 (Grab)	Clay	CLAY AND SILT, little sand , trace gravel, poorly graded, brown matrix, sub-rounded, moist, mid-plasticity, cohesive, massive	
12	825				

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PROJECT: Minto
CLIENT: Minto Exploration Ltd.

HOLE ID: 14-SWC-978
LOCATION: Yukon
PROJECT NO: 1CM002.037
DRILLING CONTRACTOR: Driftwood
DRILLING TYPE & CORE DIA: HQ Diamond
LOGGED BY: MJM
BORING DATE: Oct/Nov 2014

COORDINATES: 385122.4 E 6944219 N
DATUM: UTM Zone 8
GROUND ELEV (m): 837.2
AZIMUTH: 0
COLLAR DIP: -90
EOH ELEV. (m): 825.9
TOTAL DEPTH (m): 11.3
DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Clay, Silt, Sand, Gravel, Boulder, Bedrock, Cobbles

Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Recovery % (0 20 40 60 80 100)	Sample Type (Grab, SPT)	USCS	Soil Description	Drilling Notes & Additional Comments
14	823					
16						

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Capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID: **14-SWC-979**
LOCATION: Yukon
PROJECT NO: 1CM002.037
DRILLING CONTRACTOR: Driftwood
DRILLING TYPE & CORE DIA: HQ Diamond
LOGGED BY: MJM
BORING DATE: Oct/Nov 2014

COORDINATES: 385218.8 E 6944233 N
DATUM: UTM Zone 8
GROUND ELEV (m): 826.9
AZIMUTH: 0
COLLAR DIP: -90
EOH ELEV. (m): 795.4
TOTAL DEPTH (m): 31.5

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Legend: Moisture Content, Liquid Limit, Plastic Limit (%)

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
~0.9	~826	MM-1013 12	Organics	ORGANICS, few clay and silt, trace sand , poorly graded, Brown/Black, sub-rounded, moist, mid-plasticity, cohesive, massive	Mixed black humus and dark grey silt/sand, roots, branches, even trunk fragments scattered throughout
~9.9		MM-1013 13	Silt	CLAY AND SILT, some silt, trace sand , poorly graded, dark brown/grey, sub-rounded, moist, mid-plasticity, cohesive, massive	Contact sharp with overlying organics, large intervals of washed out zones with clean gravel
~10.5		MM-1013 14	Silt	CLAY AND SILT, little silt, trace gravel, poorly graded, black/dark bbrown, sub-angular, moist, mid-plasticity, cohesive, massi	Primarily clay/minor silt unit, black oily look when wet, popssibly glaciolacustrine
~12.3		MM-1013 15	Silt	CLAY AND SILT, few silt, few sand , gap graded, black/dy grey/brown, sub-angular, moist, mid-plasticity, cohesive, laminated	Crudely laminated sand with clay interbeds, vertical zonation of clay and sand, possible ball and plume structures, possibly gl

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PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID:	14-SWC-979	COORDINATES:	385218.8 E 6944233 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	826.9
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	795.4
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	31.5

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%): 0, 20, 40, 60, 80, 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments	PSD
14		MM-1013 16		SILT, few sand , few gravel, poorly graded, grey brown, sub-angular, moist, non-plastic, non-cohesive, massive	Ablation till - granular to cobble lithic and volcanic clasts in a silty sandy matrix	
	812					
16						
	810					
18						
	808					
20						
	806	MM-1013 17		CLAY AND SILT, some clay, trace sand , poorly graded, brown, sub-angular, wet, non-plastic, non-cohesive, massive	Massive nondescript clay/silt unit, localized saturation; possibly glaciolacustrine	0/21/77/2
22						
	804					
24						
	802					
26		MM-1013 18		SILT, few clay, trace sand , poorly graded, brown, rounded, moist,	Massive nondescript silt unit; possibly glaciolacustrine	

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HOLE ID:	14-SWC-979
LOCATION:	Yukon
PROJECT NO:	1CM002.037
DRILLING CONTRACTOR:	Driftwood
DRILLING TYPE & CORE DIA:	HQ Diamond
LOGGED BY:	MJM
BORING DATE:	Oct/Nov 2014
COORDINATES:	385218.8 E 6944233 N
DATUM:	UTM Zone 8
GROUND ELEV (m):	826.9
AZIMUTH:	0
COLLAR DIP:	-90
EOH ELEV. (m):	795.4
TOTAL DEPTH (m):	31.5

PROJECT: Minto
CLIENT: Minto Exploration Ltd.
DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content; Liquid Limit; Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
26				non-plastic, non-cohesive, massive	
28	800				
	798	MM-1013 19	Silt	SILT, few clay, few gravel, poorly graded, brown/tan, sub-rounded, dry, non-plastic, non-cohesive, massive	Possibly basal till; tan silty matrix with granular to pebble mostly igneous to volcanic clasts
30	796	MM-1013 20	Sand	SAND, trace clay, trace silt, poorly graded, orangegrey, sub-rounded, moist, non-plastic, non-cohesive, massive	Highly oxidized granodiorite regolith, very soft, crumbles to grus under hand pressure
32	794				
34	792				
36	790				

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HOLE ID:	14-SWC-980	COORDINATES:	385194.5 E 6944261 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	826.5
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	804.9
LOGGED BY:	MJM	TOTAL DEPTH (m):	21.6
BORING DATE:	Oct/Nov 2014	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample	USCS	Soil Description	Drilling Notes & Additional Comments
0	826				
2	824				
4	822	MM-1013 21	Silt	SILT, few sand , few gravel, poorly graded, brown, sub-rounded, moist, non-plastic, cohesive, massive	Diamictic till; silty matrix
6	820				
8	818	MM-1013 22	Clay	CLAY, few sand , little gravel, poorly graded, grey/brown, sub-rounded, moist, mid-plasticity, cohesive, massive	Massive clay with lenses of sand; bedding non apparent
10	816				
12	814	MM-1013 23	Clay	CLAY, some silt, little gravel, poorly graded, grey/brown, sub-angular, moist, mid-plasticity, cohesive, massive	Clay with discontinous sand lenses; bedding non-apparent

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Capstone MINTO MINE

HOLE ID:	14-SWC-980
LOCATION:	Yukon
PROJECT NO:	1CM002.037
DRILLING CONTRACTOR:	Driftwood
DRILLING TYPE & CORE DIA:	HQ Diamond
LOGGED BY:	MJM
BORING DATE:	Oct/Nov 2014
COORDINATES:	385194.5 E 6944261 N
DATUM:	UTM Zone 8
GROUND ELEV (m):	826.5
AZIMUTH:	0
COLLAR DIP:	-90
EOH ELEV. (m):	804.9
TOTAL DEPTH (m):	21.6
DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%)

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample	USCS	Soil Description	Drilling Notes & Additional Comments	PSD
14	812	MM-1013 24	Silt	CLAY AND SILT, few sand , trace gravel, poorly graded, brown/grey, sub-rounded, moist, mid-plasticity, cohesive, massive	Same as above, clay with silty, sandy discontinous lenses, infrequent granule to cobble volcanic, lithic and igneous clasts	
16	810					
18	808	MM-1013 25	Silt	SILT, few sand , trace gravel, poorly graded, brown, sub-angular, moist, non-plastic, non-cohesive, massive	Non-descript massive silty unit, few clasts; possibly glaciolacustrine	
20	806	MM-1013 26	Clay	CLAY, little silt, trace sand , poorly graded, brown, sub-angular, moist, mid-plasticity, cohesive, massive	Massive clay; possibly glaciolacustrine	6/40/52/2
22	804	MM-1013 27	Silt	SILT, some sand , little gravel, poorly graded, brown/orange, sub-angular, moist, non-plastic, non-cohesive, massive	Sandy ablation till with fragments of granodirite - malachite; angular sharp contact with underlying bedrock (granodiorite) at	
24	802					

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Capstone MINTO MINE

HOLE ID:	**14-SWC-981**	COORDINATES:	385148 E 6944188 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	837.838
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	807.89
LOGGED BY:	MJM	TOTAL DEPTH (m):	29.95
BORING DATE:	Oct/Nov 2014	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m): 0, 2, 4, 6, 8, 10, 12

Elev (m): 836, 834, 832, 830, 828, 826

Recovery %: 0 20 40 60 80 100

USCS	Soil Description	Drilling Notes & Additional Comments
	SAND, few silt, trace gravel, poorly graded, dark brown, sub-rounded, moist, non-plastic, non-cohesive, massive	Organic matter (tree root) for initial 10 cm
	SAND, few gravel, poorly graded, brown, sub-rounded, moist, non-plastic, non-cohesive, massive	No recovery (loss of matrix sand) from 5.4-6.9m
	CLAY AND SILT, few sand , little gravel, poorly graded, grey brown, sub-rounded, moist, mid-plasticity, cohesive, massive	
	SAND, some gravel, trace silt, poorly graded, brown, sub-rounded, moist, non-plastic, non-cohesive, massive	
	CLAY AND SILT, few gravel, little sand , poorly graded, dark grey, sub-rounded, moist, mid-plasticity, cohesive, massive	Minor organic matter including twigs

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HOLE ID:	**14-SWC-981**	COORDINATES:	385148 E 6944188 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	837.838
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	807.89
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	29.95

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

DEPOSIT AREA: Area 2

Lithological Symbol

Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Recovery %	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments
14	824					
16	822					
					SAND, few silt, little gravel, poorly graded, brown, sub-rounded, moist, non-plastic, non-cohesive, massive	
					CLAY AND SILT, little sand , little gravel, poorly graded, dark grey, sub-rounded, moist, mid-plasticity, cohesive, massive	
18	820				SAND, few clay and silt, little gravel, poorly graded, light brown, sub-rounded, moist, non-plastic, non-cohesive, massive	
20	818				CLAY AND SILT, some gravel, little sand , poorly graded, grey, sub-rounded, moist, mid-plasticity, cohesive, massive	
22	816				SAND, little gravel, poorly graded, brown, sub-rounded, moist, non-plastic, non-cohesive, massive	
24	814				CLAY AND SILT, few sand , trace gravel, poorly graded, grey brown, sub-angular, moist, low-plasticity, cohesive, massive	Very coarse gravel with clasts up to 25m
					SAND, some gravel, trace silt, poorly graded, dark brown, sub-rounded, moist, non-plastic, non-cohesive, massive	
26	812				SAND, few gravel, little clay, poorly graded, maroon, sub-angular, moist, non-plastic, cohesive, massive	

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Capstone MINTO MINE

HOLE ID:	**14-SWC-981**	COORDINATES:	385148 E 6944188 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	837.838
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM	EOH ELEV. (m):	807.89
BORING DATE:	Oct/Nov 2014	TOTAL DEPTH (m):	29.95

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Clay, Silt, Sand, Gravel, Boulder, Bedrock, Cobbles

Sample Type: Grab, SPT

Legend: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m): 26, 28, 30 — Elev (m): 810, 808, 806 — Recovery % 0 20 40 60 80 100

USCS	Soil Description	Drilling Notes & Additional Comments
Sand	SAND, some gravel, little clay, poorly graded, grey, sub-angular, moist, non-plastic, cohesive, massive	Local highly oxidized limoinitic fragments; some with malachite
Gravel	GRAVEL, little sand , maroon, sub-rounded, moist, non-plastic, non-cohesive, massive	Fines almost completely washed away; only cobbles remaining
Sand	SAND, little gravel, poorly graded, maroon, angular, moist, non-plastic, non-cohesive, massive	Probably strongly altered rock but behaving as a soil

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HOLE ID:	**15-SWC-995**	COORDINATES:	385096.08 E 6944251.64 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	839.41
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	826.66
LOGGED BY:	MJM/DM	TOTAL DEPTH (m):	13.2
BORING DATE:	5-Feb-15 To 9-Feb-15	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Legend: Moisture Content, Liquid Limit, Plastic Limit (%)

PSD Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample	USCS	Soil Description	Drilling Notes & Additional Comments	PSD
0	839.41	58552		SAND, few gravel, some silt, well graded, brown, sub-angular, wet, low plasticity, cohesive, massive	Occasional cobbles	
		58553		CLAY, few silt, some sand, poorly graded, brown, , wet, med plasticity, cohesive, massive		
				SILT, few sand, few gravel, trace clay, well graded, brown, sub-angular, wet, low plasticity, cohesive, massive	Occasional cobbles	
		58554		SILT, some sand, little gravel, little clay, well graded, brown, sub-rounded, wet, non-plastic, non-cohesive, massive	Cohesive fines; occasional cobbles	12/36/43/9
				SILT, some sand , little gravel, little clay, well graded, brown, sub-rounded, wet, non-plastic, non-cohesive, massive		
		58555		SAND, some gravel, well graded, reddish-brown, sub-angular, wet, non-plastic, non-cohesive, massive	Extremely weathered diorite. Bedrock at 13.2m	

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HOLE ID:	**15-SWC-995**	COORDINATES:	385096.08 E 6944251.64 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	839.41
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	826.66
LOGGED BY:	MJM/DM	TOTAL DEPTH (m):	13.2
BORING DATE:	5-Feb-15 To 9-Feb-15	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol

Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Moisture Content

Liquid Limit

Plastic Limit

(%)

0 20 40 60 80 100

PSD

Gravel / Sand / Silt / Clay(%)

Depth (m)

Elev (m)

Recovery %

0 20 40 60 80 100

Sample Type

Grab

SPT

USCS

Soil Description

Drilling Notes & Additional Comments

826

14

825

824

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Capstone MINTO MINE

HOLE ID:	**15-SWC-996**	COORDINATES:	385161 E 6944314.88 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	827.87
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	803.45
LOGGED BY:	MJM/DM	TOTAL DEPTH (m):	28.2
BORING DATE:	9-Feb-15 To 11-Feb-15	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%) 0–100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments	PSD
0			Silt	SILT, few sand, few gravel, little organics, poorly graded, dark brown, sub-rounded, moist, low plasticity, cohesive, massive		
		Grab 58556	Sand	SAND, some silt, few gravel, trace boulder, poorly graded, brown, sub-rounded, moist, low plasticity, cohesive, massive	Occasional cobbles up to 13cm	
2	826					
4	824		Clay	CLAY, few silt, well graded, dark brown-grey, rounded, moist, high plasticity, cohesive, massive	Unable to determine exact contact as next run was not fully recovered	
			Silt	SILT, few gravel, some clay, poorly graded, mottled grey-brown, sub-rounded, , low plasticity, non-cohesive, massive	Unkown parameters due to low recovery	
6	822	Grab 58557	Silt	SILT, some sand, little gravel, well graded, light brown, sub-angular, moist, med plasticity, cohesive, bedded >3cm	Bedded at 45-55 deg tca	16/35/43/6
8	820		Silt	SILT, some sand, few gravel, little boulder, poorly graded, brown, sub-angular, moist, high plasticity, cohesive, blocky	Poorly sorted, local cobbles up to 11m; locally bedded but still poorly sorted	
10	818	Grab 58558	Silt	SILT, some sand, little gravel, well graded, dark/light brown, sub-rounded, moist, med plasticity, cohesive, thinly bedded >0.5		
12	816				No recovery; Lost Core	
			Sand	SAND, few gravel, few silt, poorly graded, brown-grey, rounded, moist,		

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Capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID:	**15-SWC-996**	COORDINATES:	385161 E 6944314.88 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	827.87
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	803.45
LOGGED BY:	MJM/DM	TOTAL DEPTH (m):	28.2
BORING DATE:	9-Feb-15 To 11-Feb-15	DEPOSIT AREA:	Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%): 0, 20, 40, 60, 80, 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample	USCS	Soil Description	Drilling Notes & Additional Comments	PSD
			Sand	low plasticity, cohesive, blocky		
14	814	58559	Sand	SAND, few silt, few gravel, well graded, brown, sub-angular, moist, low plasticity, cohesive, bedded >3cm	Mod-well bonded; bedding at 50 deg tca. 15.20 - 15.54m; soft mud/clay/sand mix, appears to be artificial/drill induced.	11/30/51/8
			Silt	SILT, few sand, little gravel, well graded, brown-grey, sub-rounded, wet, low plasticity, cohesive, massive	Some wash out from 20.2-21.7 likely caused due to reeming since bit started off bottom on this run	
16	812		Sand	SAND, some silt, few gravel, poorly graded, brown, sub-rounded, wet, med plasticity, cohesive, massive		
18–20	810–808	58560	Silt	SILT, some sand, little gravel, poorly graded, brown, sub-rounded, moist, low plasticity, cohesive, massive	Significant colour change at end of unit	
22	806	58561	Sand	SAND, few gravel, poorly graded, reddish brown, sub-angular, moist, low plasticity, cohesive, massive	Unit is composed of highly weathered bedrock material; brecciated appearance	
24–26	804–802		Bedrock	BEDROCK		

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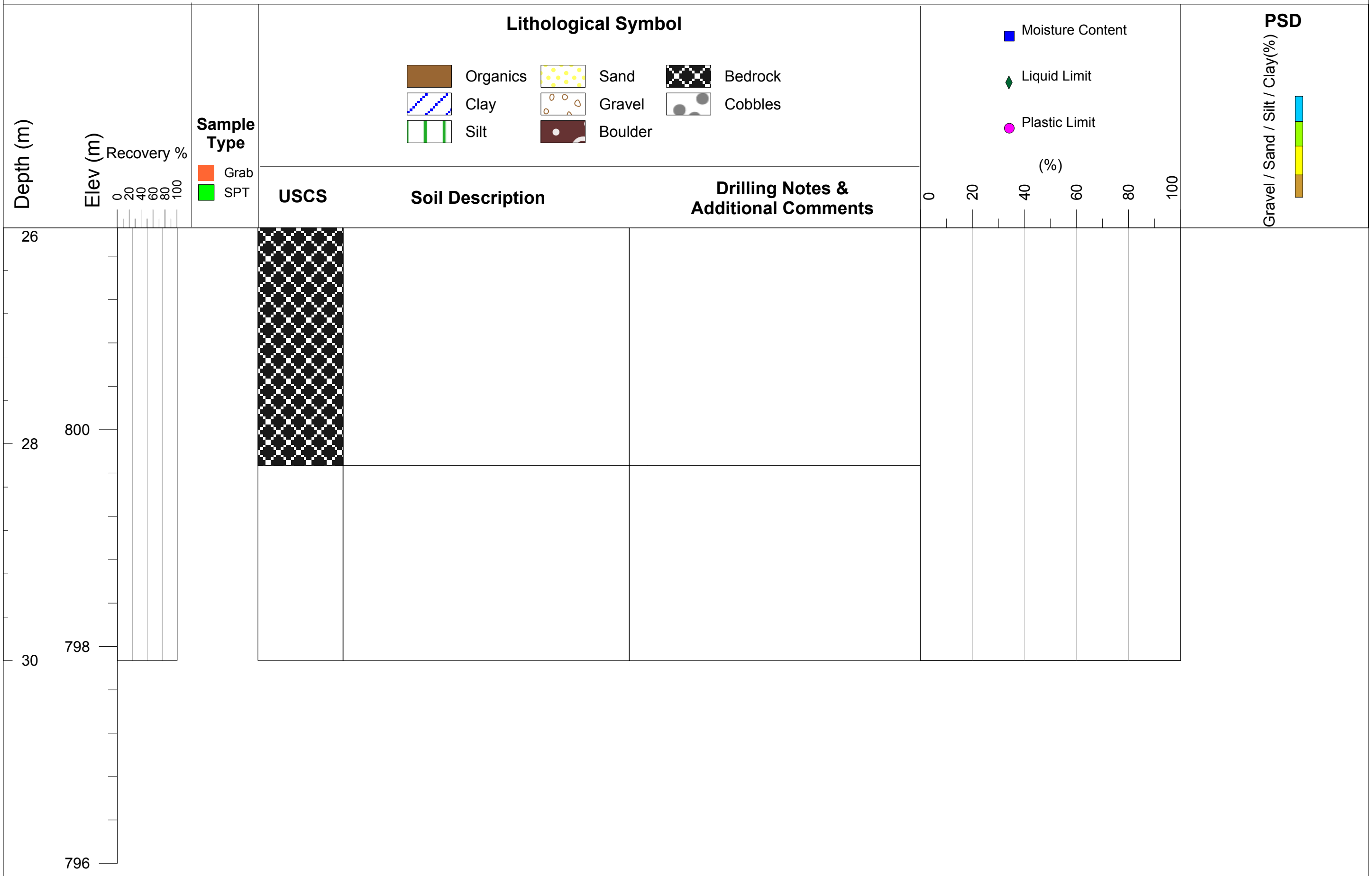
Capstone
MINTO MINE

HOLE ID:	**15-SWC-996**	COORDINATES:	385161 E 6944314.88 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	827.87
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
		COLLAR DIP:	-90
DRILLING TYPE & CORE DIA:	HQ Diamond	EOH ELEV. (m):	803.45
LOGGED BY:	MJM/DM	TOTAL DEPTH (m):	28.2
BORING DATE:	9-Feb-15 To 11-Feb-15	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.



HOLE ID:	**15-SWC-997**	COORDINATES:	385140.87 E 6944123.97 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	841.65
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM/DM	EOH ELEV. (m):	789.65
BORING DATE:	12-Feb-15 To 14-Feb-15	TOTAL DEPTH (m):	52.8

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Moisture Content; Liquid Limit; Plastic Limit (%)

PSD: Gravel / Sand / Silt / Clay(%)

Sample Type: Grab, SPT

Depth (m)	Elev (m)	Sample Type	Soil Description	Drilling Notes & Additional Comments	PSD
0		58562 (Grab)	GRAVEL, some sand, little silt, well graded, grey-brown, sub-rounded, wet, non-plastic, non-cohesive, massive	Occasional cobble; spoor recovery in this unit; evidence of cobble and gravels gettig stuck and spun in the bit which likely di	
	840				
4			GRAVEL, some sand, little silt, well graded, grey-brown, sub-rounded, wet, non-plastic, non-cohesive, massive	Assumed to be the same as recorded on the first hole; nothing suggests otherwise; no salt brine was used for the first 3.8m to	
				Poor recovery; indicates same a soil above; core barrel lot down hole requiring re-drill hole.	
6	836		GRAVEL, some sand, little silt, well graded, grey-brown, sub-rounded, wet, non-plastic, non-cohesive, massive	Some slush within split tube suggests brine remains subfreezing during drilling process	
			COBBLES, few gravel, few sand, few silt, sub-rounded, , non-plastic, non-cohesive,	Low recovery with mostly cobbles and gravel recovered with a 7cm section of sand/silt.	
8			non-plastic, non-cohesive,	No recovery	
	832		COBBLES, few gravel, few sand, few silt, sub-rounded, , non-plastic, non-cohesive,	Low recovery with mostly cobbles and gravel recovered with a 7cm section of sand/silt.	
10		160025 (Grab)	SAND, few gravel, few silt, trace clay, poorly graded, light brown, sub-rounded, moist, low plasticity, cohesive, bedded >3cm	11.7-11.8m: 10cm silty band (with minor clay) lower cohesion, possibly larger (15cm lost recvery). Bedding locally apparent at	30/42/24/4
12		58563 (Grab)			

HOLE ID:	15-SWC-997	COORDINATES:	385140.87 E 6944123.97 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	841.65
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM/DM	EOH ELEV. (m):	789.65
BORING DATE:	12-Feb-15 To 14-Feb-15	TOTAL DEPTH (m):	52.8

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample	USCS	Soil Description	Drilling Notes & Additional Comments
14	828	58564		SILT, some sand, few gravel, trace boulder, poorly graded, light brown, sub-rounded, moist, low plasticity, cohesive, massive	Similar to previous unit but no bedding aparent.
16		58565			
		58566		CLAY, some silt, few sand, trace gravel, well graded, dark grey brown, sub-angular, moist, high plasticity, cohesive, thinly be	mm to cm scale clay rich beds, local sandier beds. Bedding at 68 deg tca.
18	824			SAND, some silt, little gravel, trace boulder, poorly graded, light grey brown, sub-angular, moist, low plasticity, cohesive, m	
				SAND, some silt, little organics, little clay, well graded, dark grey, sub-angular, moist, med plasticity, cohesive, thinly bed	18.9-19.13m: wood. Locally decomposed but mostly well preserved; immediately below this is a 6cm sand/gravel bed containing 15%
20		58567			
				CLAY, some silt, few sand, trace organics, poorly graded, dark grey, sub-angular, moist, high plasticity, cohesive, massive	
	820			SAND, few silt, little gravel, well graded, grey, sub-angular, moist, non-plastic, cohesive, thinly bedded >0.5cm	
22				BOULDER, pink-grey, sub-angular, dry, non-plastic, cohesive, blocky	Granite boulder
				CLAY, few silt, little sand, well graded, grey, sub-angular, moist, high plasticity, cohesive, massive	
		58568		GRAVEL, few sand, few silt, little clay, poorly graded, grey, sub-angular, moist, non-plastic, cohesive, thinly bedded >0.5cm	Trace organics present
24					PSD: 44/29/21/6
26	816			SAND, some silt, little gravel, trace boulder, well graded, grey-brown, sub-angular, moist, non-plastic, cohesive, thinly bedde	One 20cm boulder

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Capstone MINTO MINE

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

HOLE ID:	15-SWC-997	COORDINATES:	385140.87 E 6944123.97 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	841.65
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
LOGGED BY:	MJM/DM	EOH ELEV. (m):	789.65
BORING DATE:	12-Feb-15 To 14-Feb-15	TOTAL DEPTH (m):	52.8

DEPOSIT AREA: Area 2

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Sample Type: Grab, SPT

Moisture Content, Liquid Limit, Plastic Limit (%)

PSD: Gravel / Sand / Silt / Clay(%)

Depth (m)	Elev (m)	Sample	USCS	Soil Description	Drilling Notes & Additional Comments
26 – 27.7			Sand		
27.7 – 28.6		58569	Silt	SILT, some sand, little clay, trace organics, well graded, light-med brown, sub-angular, moist, med plasticity, cohesive, thinl	
28.6 – 30.25	812		Sand	SAND, few gravel, little silt, poorly graded, mottled brown, sub-rounded, moist, non-plastic, cohesive, massive	Locally non-cohesive
30.25 – 33.05		58570	Sand	SAND, some silt, little gravel, well graded, med brown, sub-rounded, moist, non-plastic, cohesive, bedded >3cm	Very well graded; (coarse sand beds and fine silt beds) 75 deg tca bedding
33.05 – 34.3	808	58571	Sand	SAND, few gravel, few silt, well graded, mottled brown, sub-rounded, moist, non-plastic, cohesive, bedded >3cm	
34.3 – 37.95	804		Silt	SILT, few sand, little gravel, trace boulder, well graded, med brown, sub-rounded, moist, non-plastic, cohesive, bedded >3cm	
37.95 – 38.8			Sand	SAND, few gravel, little silt, little boulder, poorly graded, mottled brown, sub-angular, moist, non-plastic, cohesive, blocky	Occasional cobble/boulder
38.8 –			Sand	SAND, few gravel, little boulder, little	

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Capstone MINTO MINE

HOLE ID:	**15-SWC-997**	COORDINATES:	385140.87 E 6944123.97 N
LOCATION:	Yukon	DATUM:	UTM Zone 8
PROJECT NO:	1CM002.037	GROUND ELEV (m):	841.65
DRILLING CONTRACTOR:	Driftwood	AZIMUTH:	0
DRILLING TYPE & CORE DIA:	HQ Diamond	COLLAR DIP:	-90
		EOH ELEV. (m):	789.65
LOGGED BY:	MJM/DM	TOTAL DEPTH (m):	52.8
BORING DATE:	12-Feb-15 To 14-Feb-15	DEPOSIT AREA:	Area 2

PROJECT: Minto

CLIENT: Minto Exploration Ltd.

Lithological Symbol: Organics, Sand, Bedrock, Clay, Gravel, Cobbles, Silt, Boulder

Legend: Moisture Content, Liquid Limit, Plastic Limit (%) 0 20 40 60 80 100

PSD Gravel / Sand / Silt / Clay(%)

Sample Type: Grab, SPT

Depth (m) | Elev (m) | Recovery % 0 20 40 60 80 100

Depth (m)	Elev (m)	Sample	USCS	Soil Description	Drilling Notes & Additional Comments	PSD
to ~41.0			Sand	silt, poorly graded, mottled brown, sub-angular, moist, non-plastic, non-cohesive, blo		
~41.0–45.8	800	58572 (Grab)	Silt	SILT, few clay, some sand, few gravel, poorly graded, grey, sub-angular, moist, med plasticity, cohesive, massive		15/34/29/2 2
~45.8	796	58573 (Grab)	Silt	SILT, few clay, few gravel, few sand, poorly graded, grey, sub-rounded, moist, med plasticity, cohesive, massive	Unknown lower contact due to poor recovery, assumed to end early since this sort of soil has historically had better recovery t	
~46.2		58571 (Grab)	Gravel	GRAVEL, some sand, little silt, well graded, grey-brown, sub-angular, moist, non-plastic, non-cohesive, massive	Poor recovery throughout this unit	
~50.5	792		Sand	SAND, little silt, few gravel, well graded, red-brown, sub-rounded, moist, non-plastic, cohesive, massive		

Depth markers: 40, 42, 44, 46, 48, 50, 52. Elevation markers: 800, 796, 792.

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HOLE ID: **15-SWC-997**
LOCATION: Yukon
PROJECT NO: 1CM002.037
DRILLING CONTRACTOR: Driftwood
DRILLING TYPE & CORE DIA: HQ Diamond
LOGGED BY: MJM/DM
BORING DATE: 12-Feb-15 To 14-Feb-15

COORDINATES: 385140.87 E 6944123.97 N
DATUM: UTM Zone 8
GROUND ELEV (m): 841.65
AZIMUTH: 0
COLLAR DIP: -90
EOH ELEV. (m): 789.65
TOTAL DEPTH (m): 52.8

PROJECT: Minto
CLIENT: Minto Exploration Ltd.

DEPOSIT AREA: Area 2

Lithological Symbol

Organics, Clay, Silt, Sand, Gravel, Boulder, Bedrock, Cobbles

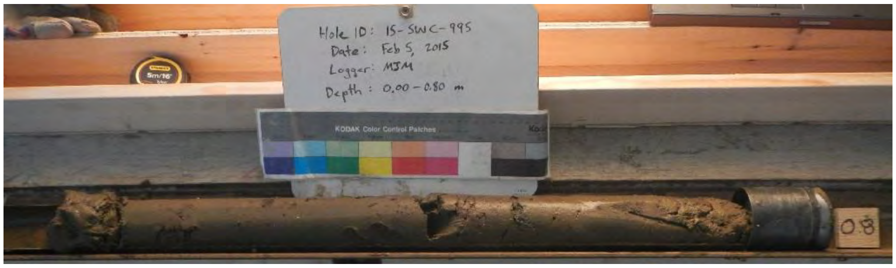
Sample Type: Grab, SPT

Moisture Content
Liquid Limit
Plastic Limit

PSD

Depth (m)	Elev (m)	Recovery % (0 20 40 60 80 100)	Sample Type	USCS	Soil Description	Drilling Notes & Additional Comments	(%) 0 20 40 60 80 100	Gravel / Sand / Silt / Clay(%)
	788							
54								
56								
	784							

Attachment 2: Core Photos

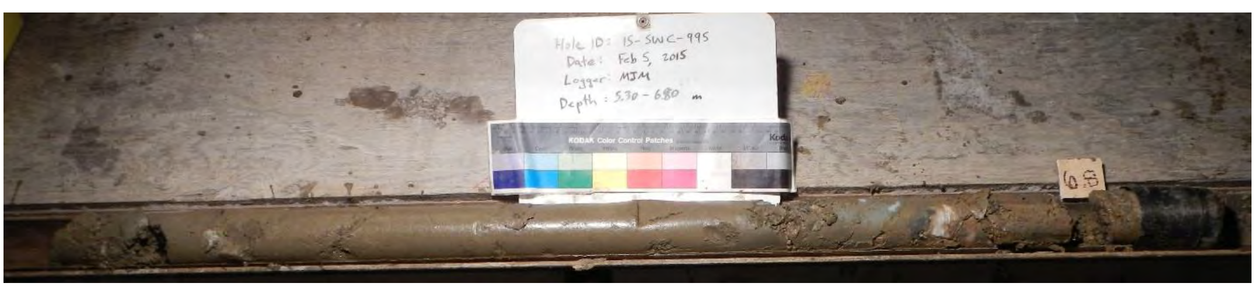


15-SWC-995: 0 m - 0.8 m

15-SWC-995: 0.8 m - 2.3 m

15-SWC-995: 2.3 m - 3.8 m

15-SWC-995: 3.8 m - 5.3 m



15-SWC-995: 5.3 m - 6.8 m

15-SWC-995: 6.8 m - 8.3 m

15-SWC-995: 8.3 m - 9.8 m

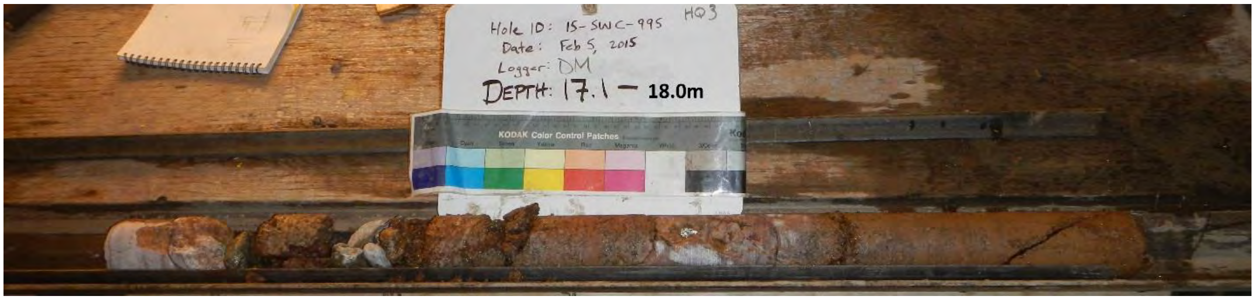
15-SWC-995: 9.8 m - 11.3 m

15-SWC-995: 11.3 m - 12.8 m

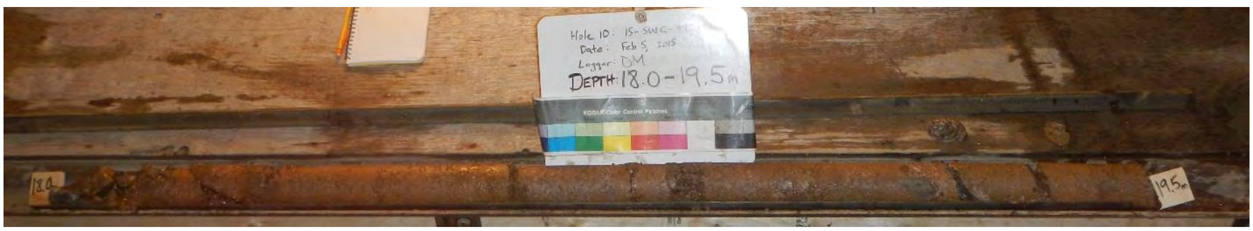
15-SWC-995: 12.8 m - 14.1 m

15-SWC-995: 14.1 m - 15.6 m

15-SWC-995: 15.6 m - 17.1 m

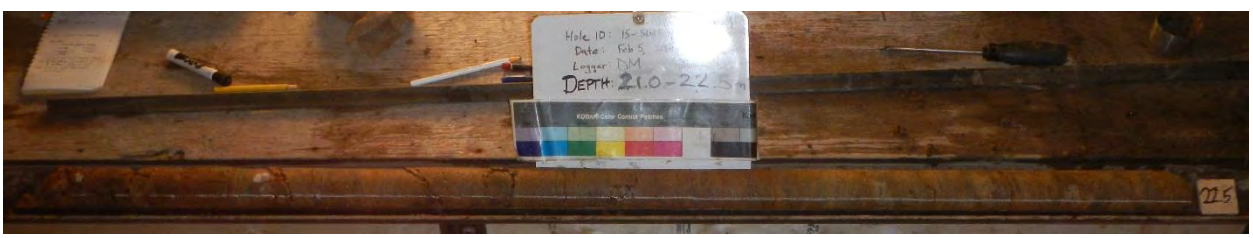


15-SWC-995: 17.1 m - 18 m



15-SWC-995: 18 m - 19.5 m

15-SWC-995: 19.5 m - 21 m



15-SWC-995: 21 m - 22.5 m

15-SWC-995: 22.5 m - 24 m

15-SWC-995: 24 m - 25.5 m

15-SWC-995: 25.5 m - 27 m

15-SWC-995: 27 m - 28.5 m

15-SWC-995: 28.5 m - 30 m

15-SWC-995: 30 m - 31.5 m

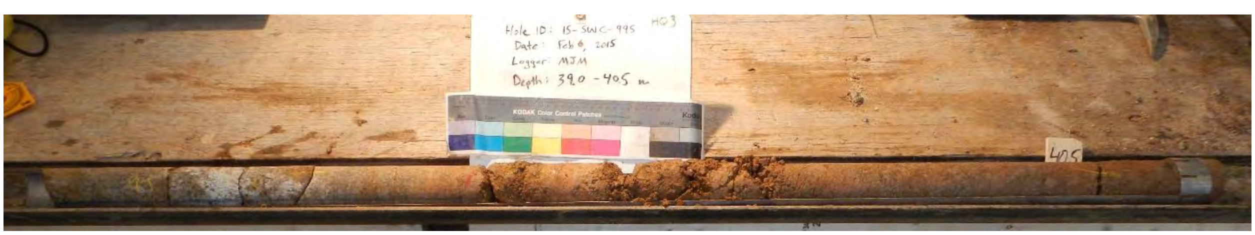
15-SWC-995: 31.5 m - 33 m

15-SWC-995: 33 m - 34.5 m

15-SWC-995: 34.5 m - 36 m

15-SWC-995: 36 m - 37.5 m

15-SWC-995: 37.5 m - 39 m



15-SWC-995: 39 m - 40.5 m

15-SWC-995: 40.5 m - 42 m

15-SWC-995: 42 m - 43.5 m

15-SWC-995: 43.5 m - 45 m

15-SWC-995: 45 m - 46.5 m

15-SWC-995: 46.5 m - 48 m

15-SWC-995: 48 m - 49.5 m

15-SWC-995: 49.5 m - 51 m

15-SWC-995: 51 m - 52.5 m

15-SWC-995: 52.5 m - 54 m

15-SWC-995: 54 m - 55.5 m

15-SWC-995: 55.5 m - 57 m

15-SWC-995: 57 m - 58.5 m

15-SWC-995: 58.5 m - 60 m

15-SWC-995: 60 m - 61.5 m

15-SWC-995: 61.5 m - 63 m

15-SWC-995: 63 m - 64.5 m

15-SWC-995: 64.5 m - 66 m

15-SWC-995: 66 m - 67.5 m

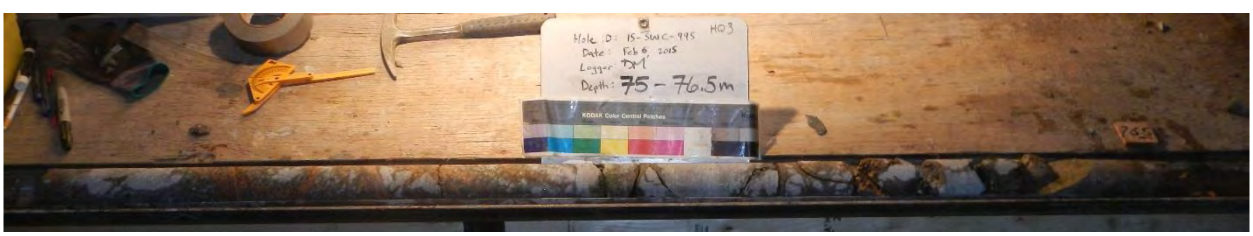
15-SWC-995: 67.5 m - 69 m

15-SWC-995: 69 m - 70.5 m

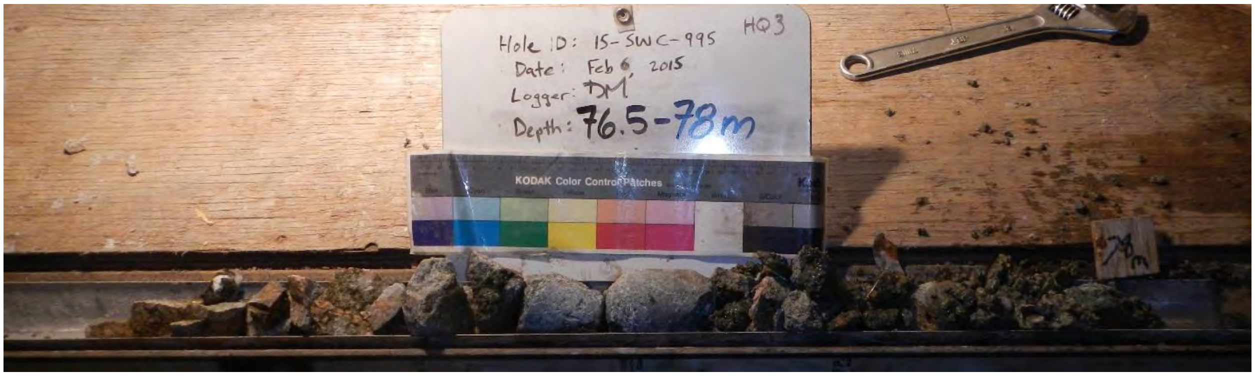
15-SWC-995: 70.5 m - 72 m

15-SWC-995: 72 m - 73.5 m

15-SWC-995: 73.5 m - 75 m



15-SWC-995: 75 m - 76.5 m



15-SWC-995: 76.5 m - 78 m

15-SWC-995: 78 m - 79.5 m

15-SWC-995: 79.5 m - 81 m

15-SWC-995: 81 m - 82.5 m

15-SWC-995: 82.5 m - 84 m

15-SWC-995: 84 m - 85.5 m

15-SWC-995: 85.5 m - 87 m

15-SWC-995: 87 m - 88.5 m

15-SWC-995: 88.5 m - 90 m

15-SWC-995: 90 m - 91.5 m

15-SWC-995: 91.5 m - 93 m

15-SWC-995: 93 m - 94.25 m

15-SWC-995: 94.25 m - 95.75 m

15-SWC-995: 95.75 m - 97.25 m

15-SWC-995: 97.25 m - 97.75 m

15-SWC-995: 97.75 m - 99.25 m

15-SWC-995: 99.25 m - 100.75 m

15-SWC-995: 100.75 m - 102.25 m

15-SWC-995: 102.25 m - 103.75 m

15-SWC-995: 103.75 m - 105 m

15-SWC-995: 105 m - 106.5 m

15-SWC-995: 106.5 m - 108 m

15-SWC-995: 108 m - 109.5 m

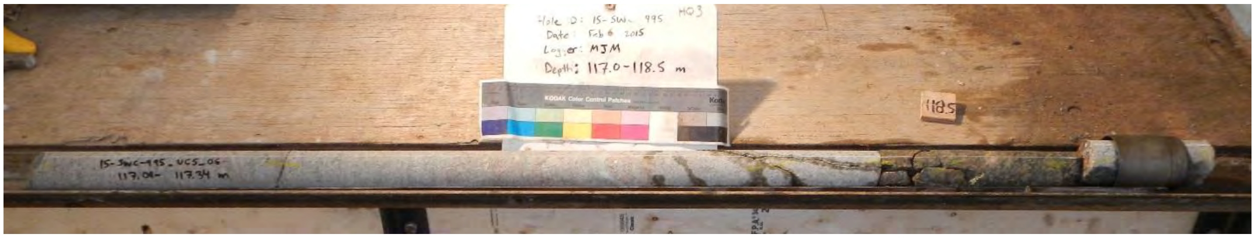
15-SWC-995: 109.5 m - 111 m

15-SWC-995: 111 m - 112.5 m

15-SWC-995: 112.5 m - 114 m

15-SWC-995: 114 m - 115.5 m

15-SWC-995: 115.5 m - 117 m



15-SWC-995: 117 m - 118.5 m

15-SWC-995: 118.5 m - 120 m

15-SWC-995: 120 m - 121.5 m

15-SWC-995: 121.5 m - 123 m

15-SWC-995: 123 m - 124.5 m

15-SWC-995: 124.5 m - 126 m

15-SWC-995: 126 m - 127.5 m

15-SWC-995: 127.5 m - 129 m

15-SWC-995: 129 m - 130.5 m

15-SWC-995: 130.5 m - 132 m

15-SWC-995: 132 m - 133.5 m

15-SWC-995: 133.5 m - 135 m

15-SWC-995: 135 m - 136.5 m

15-SWC-995: 136.5 m - 138 m

15-SWC-995: 138 m - 139.5 m

15-SWC-995: 139.5 m - 141 m

15-SWC-995: 141 m - 142.5 m

15-SWC-995: 142.5 m - 144 m

15-SWC-995: 144 m - 145.5 m

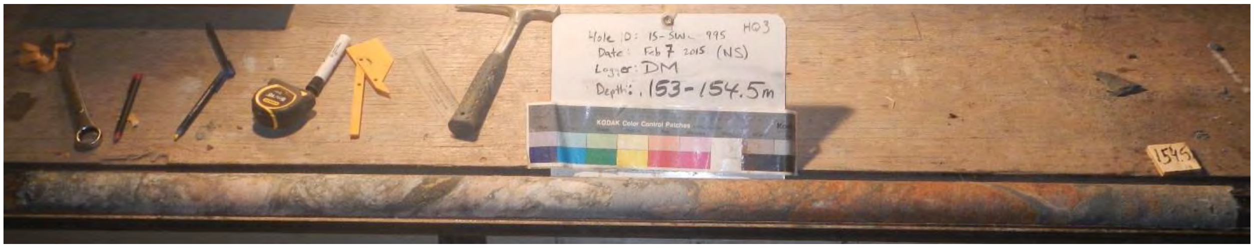
15-SWC-995: 145.5 m - 147 m

15-SWC-995: 147 m - 148.5 m

15-SWC-995: 148.5 m - 150 m

15-SWC-995: 150 m - 151.5 m

15-SWC-995: 151.5 m - 153 m



15-SWC-995: 153 m - 154.5 m

15-SWC-995: 154.5 m - 156 m

15-SWC-995: 156 m - 157.5 m

15-SWC-995: 157.5 m - 159 m

15-SWC-995: 159 m - 160.5 m

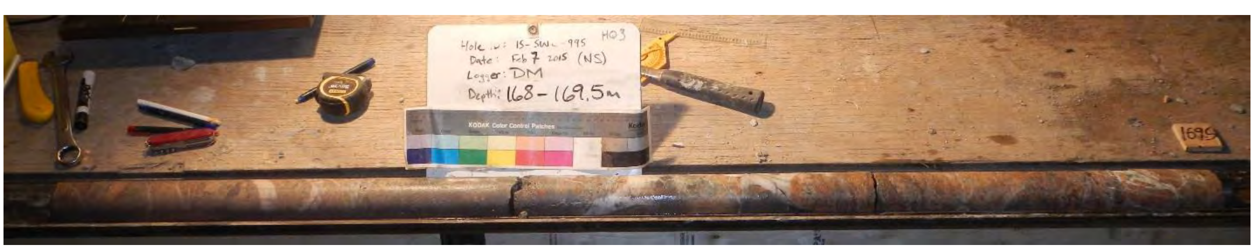
15-SWC-995: 160.5 m - 162 m

15-SWC-995: 162 m - 163.5 m

15-SWC-995: 163.5 m - 165 m

15-SWC-995: 165 m - 166.5 m

15-SWC-995: 166.5 m - 168 m

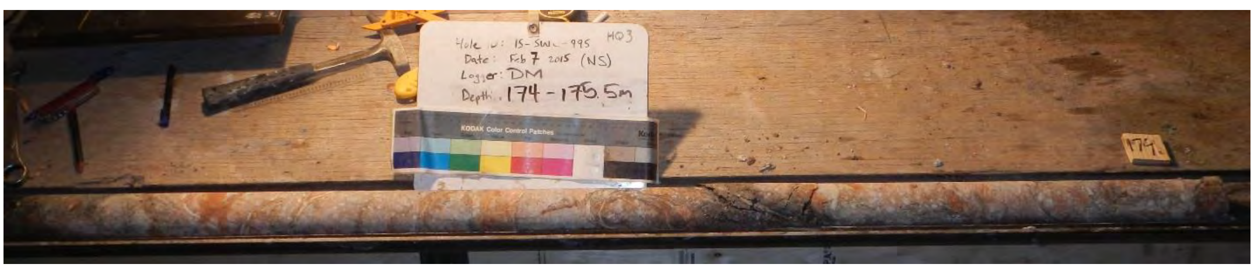


15-SWC-995: 168 m - 169.5 m

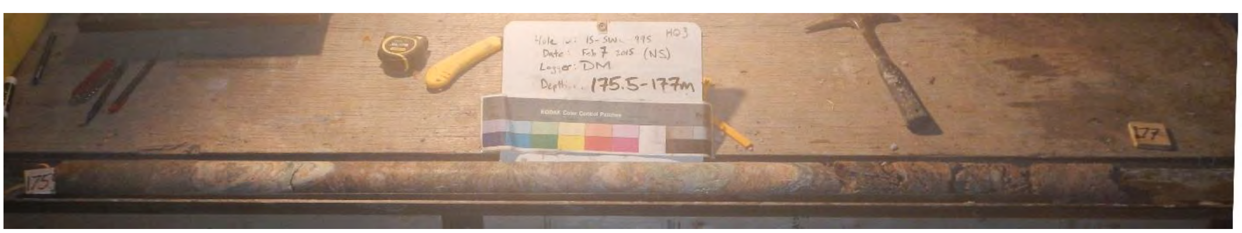
15-SWC-995: 169.5 m - 171 m

15-SWC-995: 171 m - 172.5 m

15-SWC-995: 172.5 m - 174 m



15-SWC-995: 174 m - 175.5 m

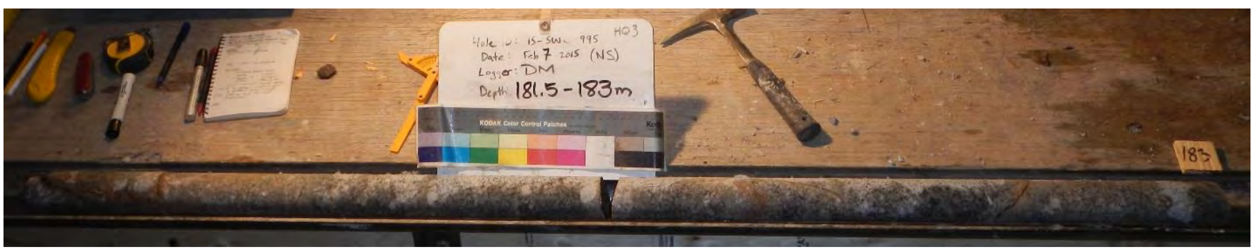


15-SWC-995: 175.5 m - 177 m

15-SWC-995: 177 m - 178.5 m

15-SWC-995: 178.5 m - 180 m

15-SWC-995: 180 m - 181.5 m



15-SWC-995: 181.5 m - 183 m

15-SWC-995: 183 m - 184.5 m

15-SWC-995: 184.5 m - 186 m

15-SWC-995: 186 m - 187.5 m

15-SWC-995: 189 m - 190.5 m

15-SWC-995: 190.5 m - 192 m

15-SWC-995: 192 m - 193.5 m

15-SWC-995: 193.5 m - 195 m

15-SWC-995: 195 m - 196.5 m

15-SWC-995: 196.5 m - 198 m

15-SWC-995: 198 m - 199.5 m

15-SWC-995: 199.5 m - 201 m

15-SWC-995: 201 m - 202.5 m

15-SWC-995: 202.5 m - 204 m

15-SWC-995: 204 m - 205.5 m

15-SWC-995: 205.5 m - 207 m

15-SWC-995: 207 m - 208.2 m

15-SWC-995: 208.2 m - 209.7 m

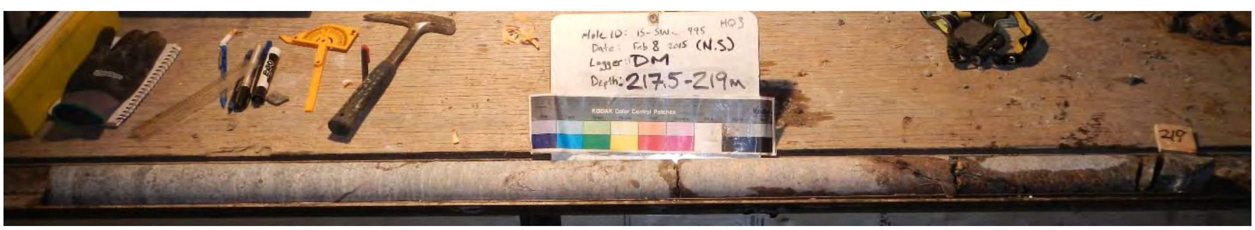
15-SWC-995: 209.7 m - 211.3 m

15-SWC-995: 211.3 m - 212.8 m

15-SWC-995: 212.8 m - 214.4 m

15-SWC-995: 214.4 m - 216 m

15-SWC-995: 216 m - 217.5 m



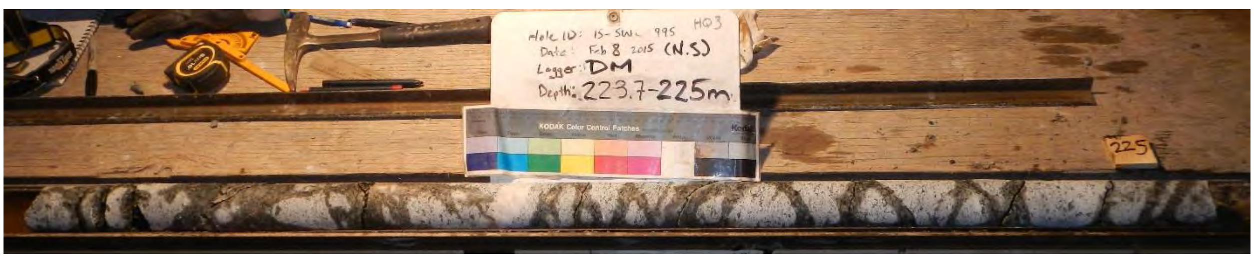
15-SWC-995: 217.5 m - 219 m

15-SWC-995: 219 m - 220.5 m

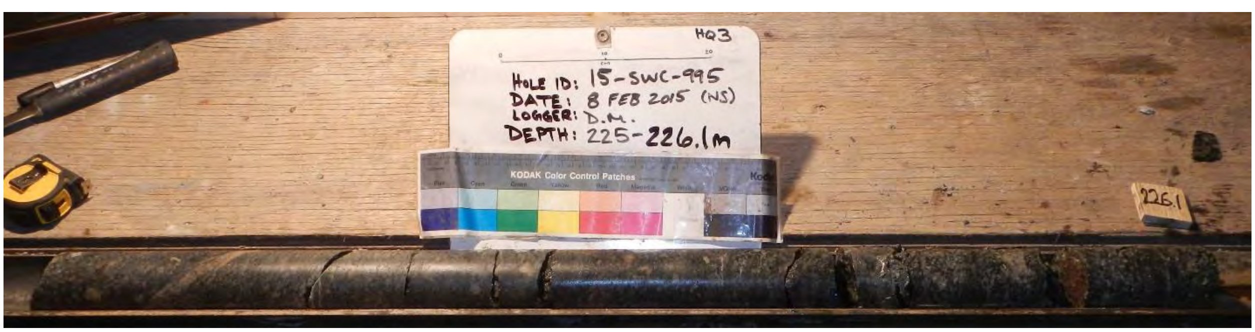
15-SWC-995: 220.5 m - 221.8 m

15-SWC-995: 221.8 m - 223.3 m

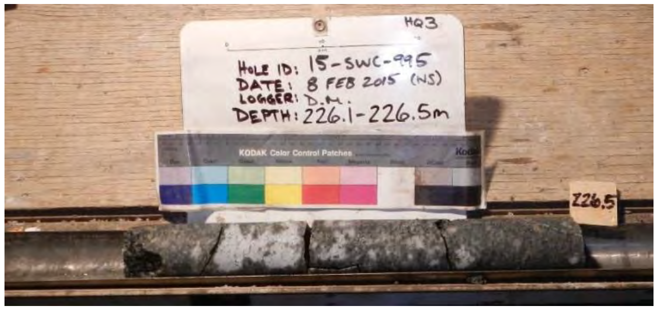
15-SWC-995: 223.3 m - 223.7 m



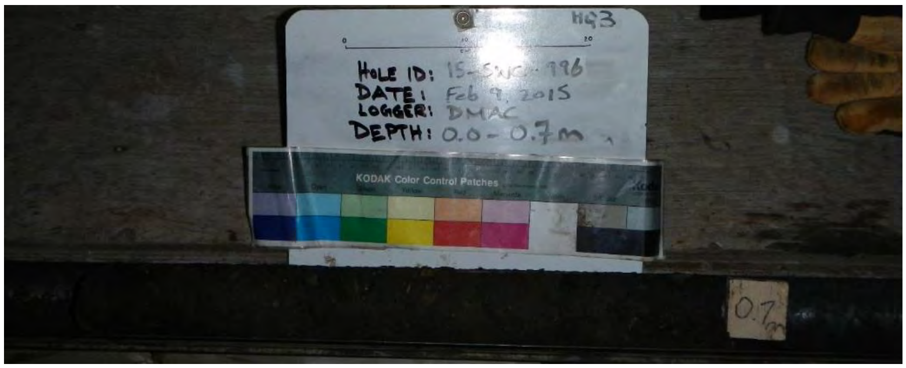
15-SWC-995: 223.7 m - 225 m



15-SWC-995: 225 m - 226.1 m

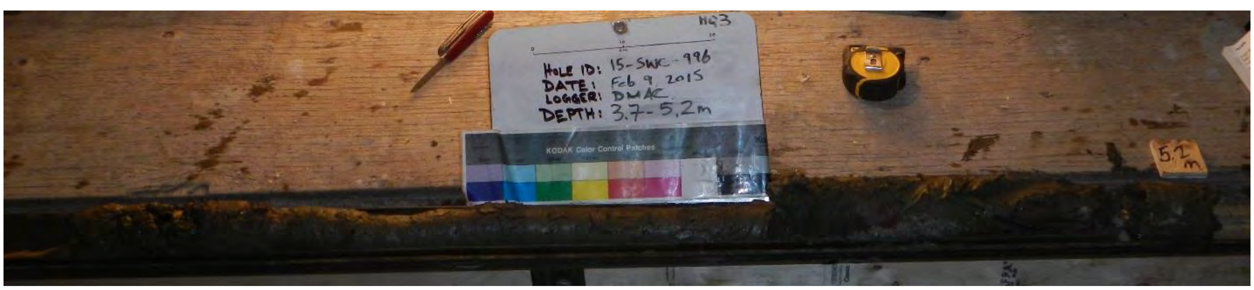


15-SWC-995: 226.1 m - 226.5 m



15-SWC-996: 0 m - 0.7 m

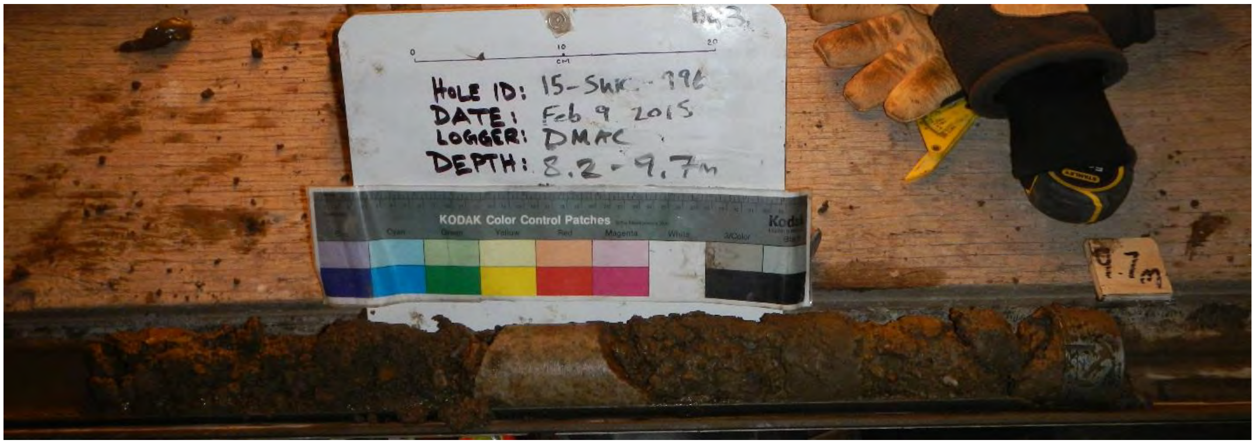
15-SWC-996: 0.7 m - 2.2 m



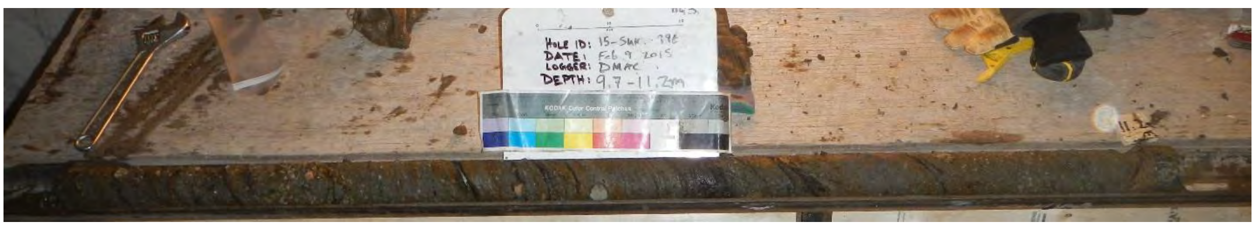
15-SWC-996: 3.7 m - 5.2 m

15-SWC-996: 5.2 m - 6.7 m

15-SWC-996: 6.7 m - 8.2 m



15-SWC-996: 8.2 m - 9.7 m



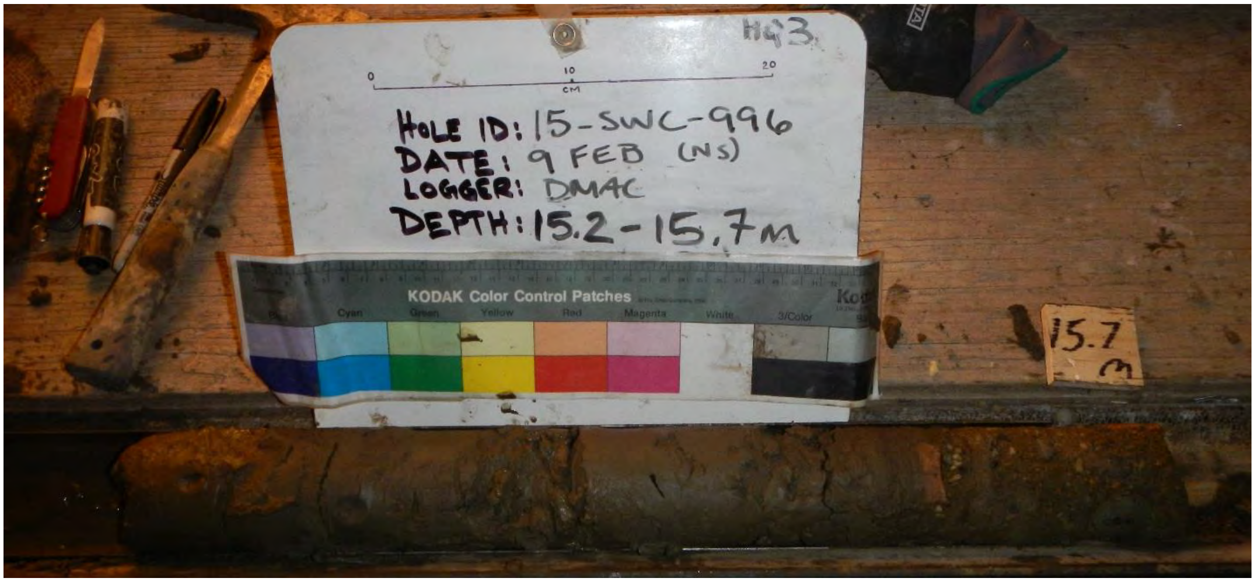
15-SWC-996: 9.7 m - 11.2 m

15-SWC-996: 11.2 m - 12.7 m

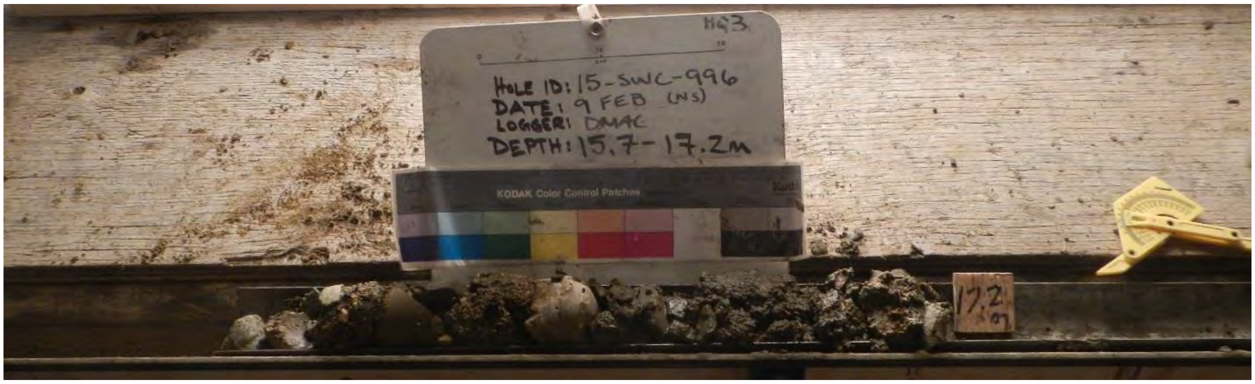
15-SWC-996: 12.7 m - 14.2 m

15-SWC-996: 13.6 m

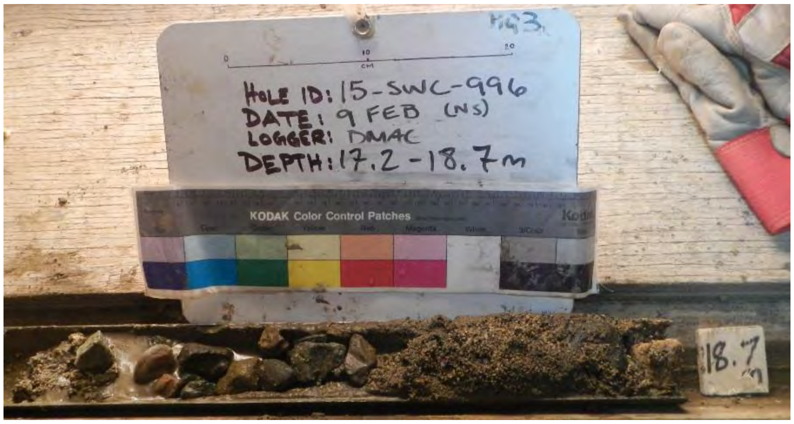
15-SWC-996: 14.2 m - 15.2 m



15-SWC-996: 15.2 m - 15.7 m

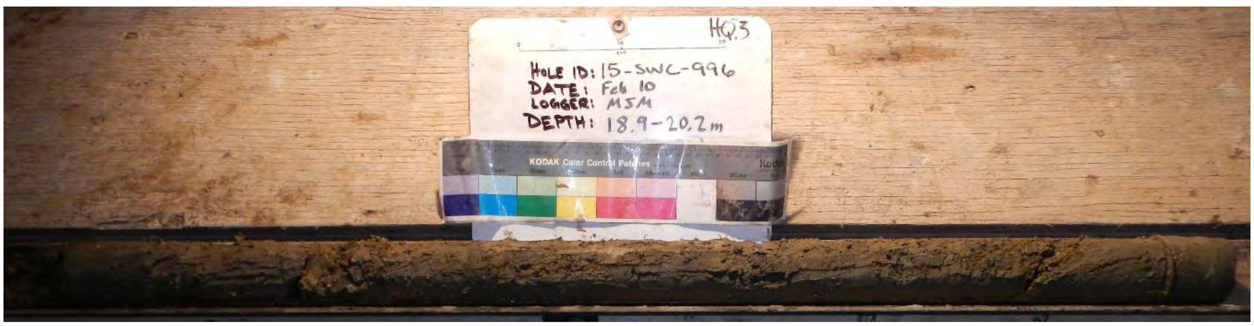


15-SWC-996: 15.7 m - 17.2 m



15-SWC-996: 17.2 m - 18.7 m

15-SWC-996: 18.7 m - 18.9 m



15-SWC-996: 18.9 m - 20.2 m

15-SWC-996: 20.2 m - 21.7 m

15-SWC-996: 21.7 m - 23.2 m

15-SWC-996: 23.2 m - 24.7 m

15-SWC-996: 24.7 m - 26.2 m

15-SWC-996: 26.2 m - 27.7 m

15-SWC-996: 27.7 m - 29.2 m

15-SWC-996: 29.2 m - 30.7 m

15-SWC-996: 30.7 m - 32.2 m

15-SWC-996: 32.2 m - 33.7 m

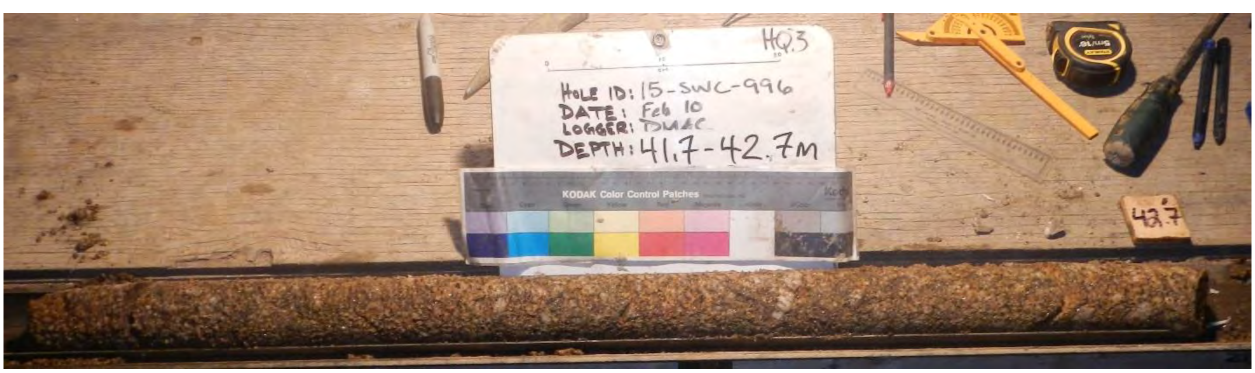
15-SWC-996: 33.7 m - 35.2 m

15-SWC-996: 35.2 m - 36.7 m

15-SWC-996: 36.7 m - 38.2 m

15-SWC-996: 38.2 m – 39.7 m

15-SWC-996: 39.7 m - 41.7 m



15-SWC-996: 41.7 m - 42.7 m

15-SWC-996: 42.7 m - 44.2 m

15-SWC-996: 44.2 m - 45.7 m

15-SWC-996: 45.7 m - 47.2 m

15-SWC-996: 47.2 m - 48.7 m

15-SWC-996: 48.7 m - 50.2 m

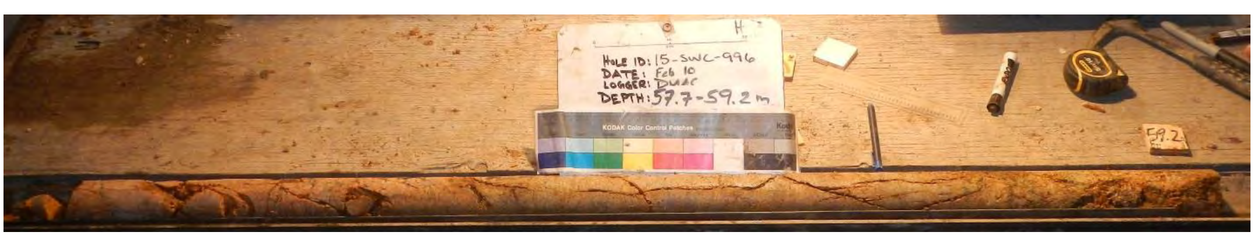
15-SWC-996: 50.2 m - 51.7 m

15-SWC-996: 51.7 m - 53.2 m

15-SWC-996: 53.2 m - 54.7 m

15-SWC-996: 54.7 m - 56.2 m

15-SWC-996: 56.2 m - 57.7 m



15-SWC-996: 57.7 m - 59.2 m

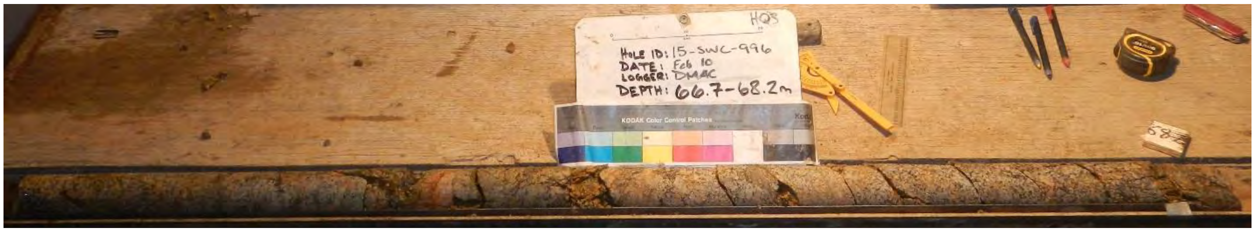
15-SWC-996: 59.2 m - 60.7 m

15-SWC-996: 60.7 m - 62.2 m

15-SWC-996: 62.2 m - 63.7 m

15-SWC-996: 63.7 m - 65.2 m

15-SWC-996: 65.2 m - 66.7 m



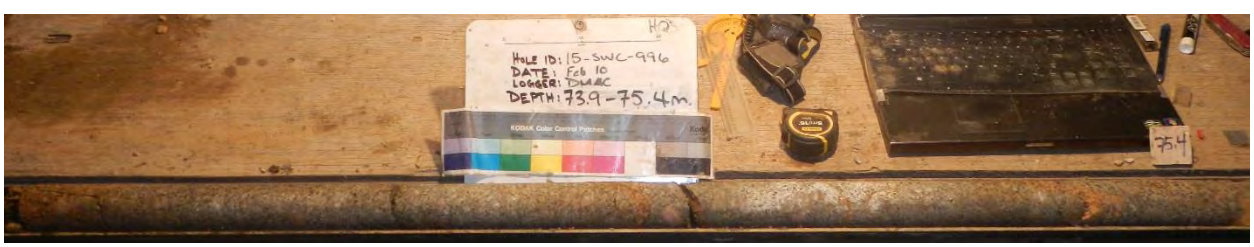
15-SWC-996: 66.7 m - 68.2 m

15-SWC-996: 68.2 m - 69.7 m

15-SWC-996: 69.7 m - 71.2 m

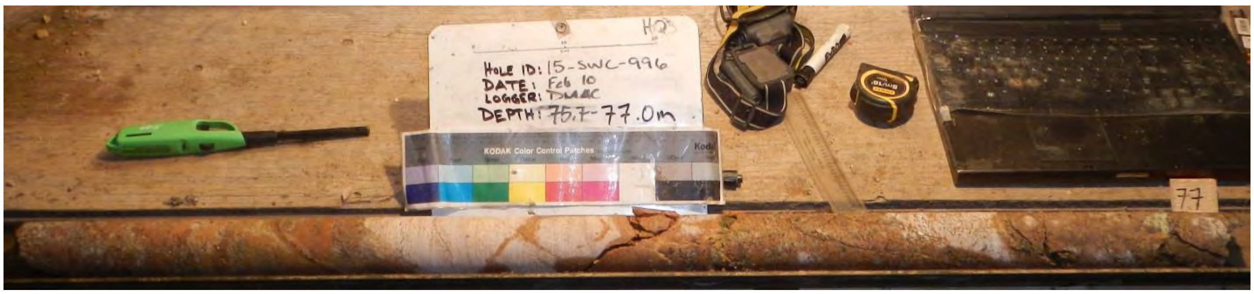
15-SWC-996: 71.2 m - 72.7 m

15-SWC-996: 72.7 m - 73.9 m

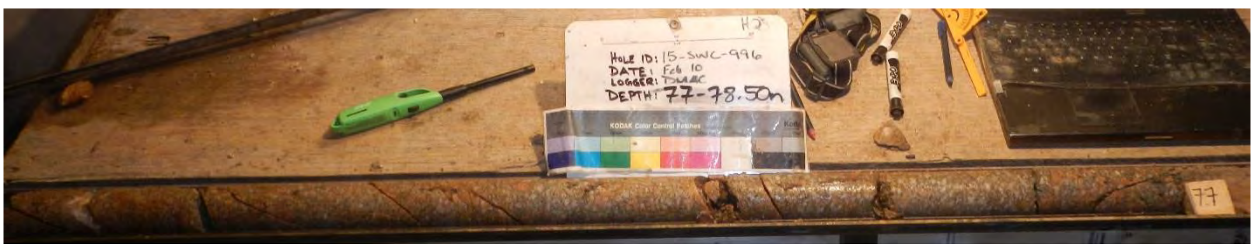


15-SWC-996: 73.9 m - 75.4 m

15-SWC-996: 75.4 m - 75.7 m



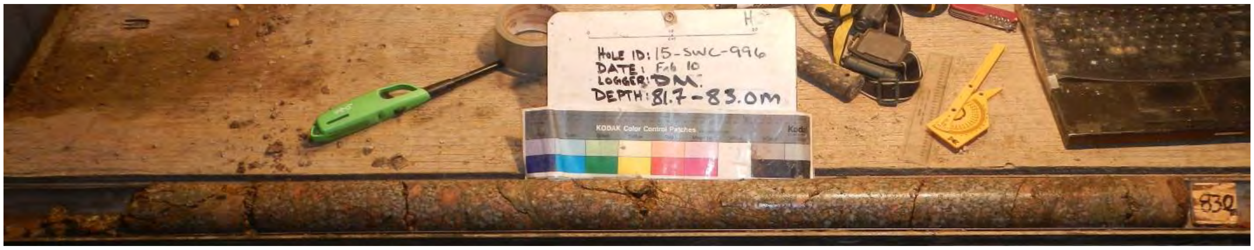
15-SWC-996: 75.7 m - 77 m



15-SWC-996: 77 m - 78.5 m

15-SWC-996: 78.5 m - 80.1 m

15-SWC-996: 80.1 m - 81.7 m



15-SWC-996: 81.7 m - 83 m

15-SWC-996: 83 m - 84.7 m

15-SWC-996: 84.7 m - 86.2 m

15-SWC-996: 86.2 m - 87.7 m

15-SWC-996: 87.7 m - 89.2 m

15-SWC-996: 89.2 m - 90.7 m

15-SWC-996: 90.7 m - 92.2 m

15-SWC-996: 92.2 m - 93.7 m

15-SWC-996: 93.7 m - 95.2 m

15-SWC-996: 95.2 m - 96.7 m

15-SWC-996: 96.7 m - 98.2 m

15-SWC-996: 98.2 m - 99.7 m

15-SWC-996: 99.7 m - 101.2 m

15-SWC-996: 101.2 m - 102.7 m

15-SWC-996: 102.7 m - 104.2 m

15-SWC-996: 104.2 m - 105.7 m

15-SWC-996: 105.7 m - 107.2 m

15-SWC-996: 107.2 m - 108.7 m

15-SWC-996: 108.7 m - 110.2 m

15-SWC-996: 110.2 m - 111.7 m

15-SWC-997: 0 m - 1.3 m

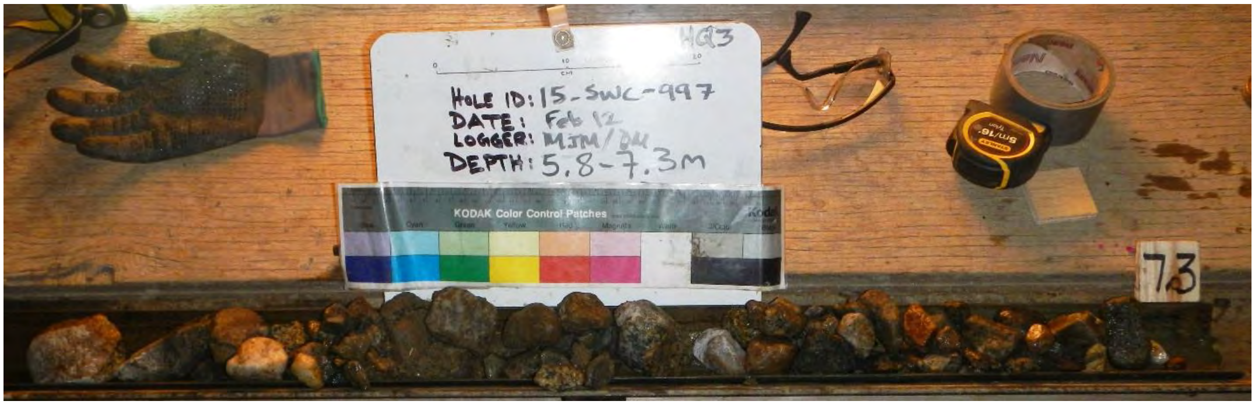
15-SWC-997: 1.3 m - 2.8 m

15-SWC-997: 2.8 m - 4.3 m

15-SWC-997: 0 m - 4.3 m re-drill

15-SWC-997: 4.3 m - 5.8 m

15-SWC-997: 4.3 m - 5.8 m re-drill

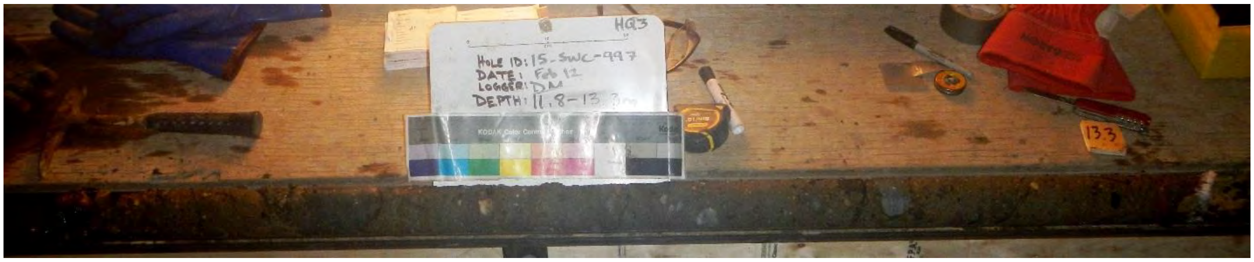


15-SWC-997: 5.8 m - 7.3 m

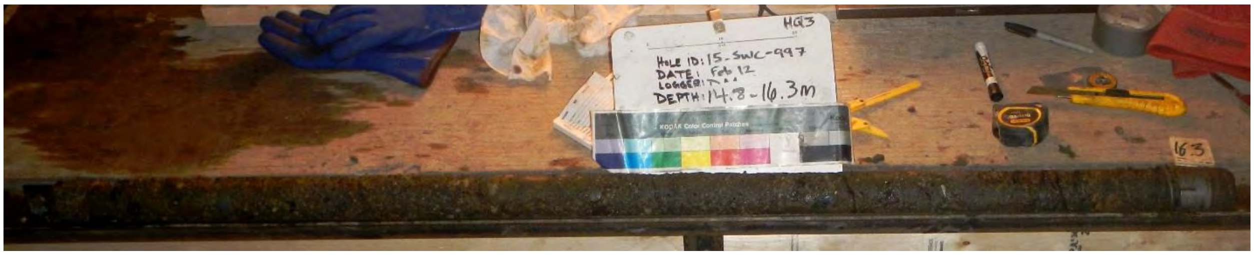
15-SWC-997: 7.3 m - 8.8 m

15-SWC-997: 8.8 m - 10.3 m

15-SWC-997: 10.3 m - 11.9 m



15-SWC-997: 11.8 m - 13.3 m



15-SWC-997: 14.8 m - 16.3 m

15-SWC-997: 16.3 m - 17.8 m

15-SWC-997: 16.9 m contact

15-SWC-997: 17.8 m - 19.3 m

15-SWC-997: 19.3 m - 20.8 m

15-SWC-997: 20.8 m - 22.3 m

15-SWC-997: 22.3 m - 23.8 m

15-SWC-997: 23.8 m - 25.3 m

15-SWC-997: 25.3 m - 26.8 m

15-SWC-997: 26.8 m - 28.3 m

15-SWC-997: 28.3 m - 29.8 m

15-SWC-997: 29.8 m - 31.3 m

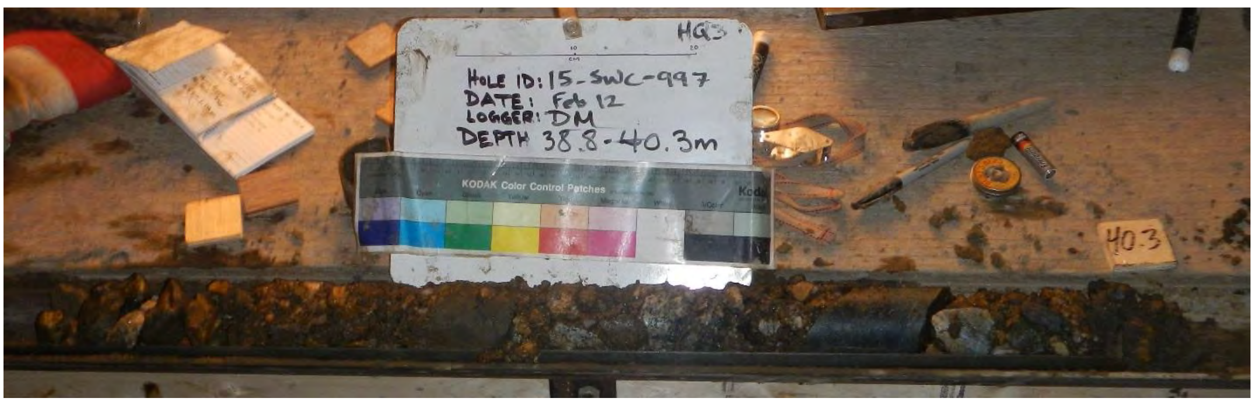
15-SWC-997: 31.3 m - 32.8 m

15-SWC-997: 32.8 m - 34.3 m

15-SWC-997: 34.3 m - 35.8 m

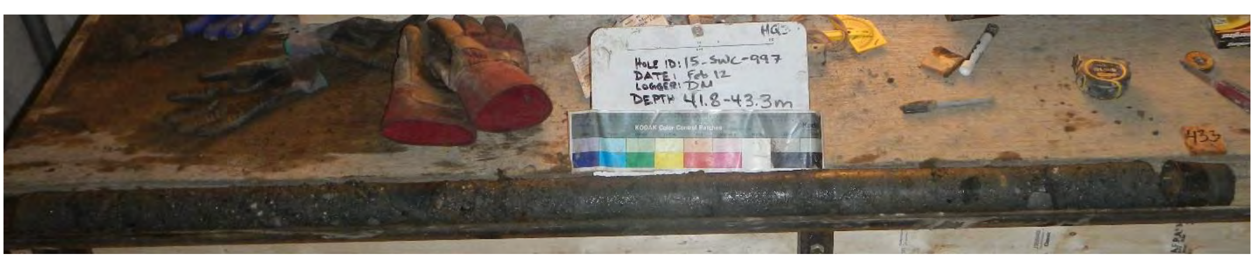
15-SWC-997: 35.8 m - 37.3 m

15-SWC-997: 37.3 m - 38.8 m



15-SWC-997: 38.8 m - 40.3 m

15-SWC-997: 40.3 m - 41.8 m



15-SWC-997: 41.8 m - 43.3 m

15-SWC-997: 43.3 m - 44.8 m

15-SWC-997: 44.8 m - 46.3 m

15-SWC-997: 46.3 m - 47.8 m

15-SWC-997: 47.8 m - 49.3 m

15-SWC-997: 49.3 m - 50.8 m

15-SWC-997: 50.8 m - 52.3 m

15-SWC-997: 52.3 m - 53.8 m

15-SWC-997: 53.8 m - 55.3 m

15-SWC-997: 55.3 m - 56.8 m

15-SWC-997: 56.8 m - 58.3 m

15-SWC-997: 58.3 m - 59.8 m

15-SWC-997: 59.8m – 61.3 m

Attachment 3: Soil Testing Results

MOISTURE CONTENT TEST RESULTS

ASTM D2216

Project:	SRK Minto Samples - Feb. 2015 Lab Testing	Sample No.:	
Project No.:	W14103546-01	Date Tested:	February 27, 2015
Client:	SRK Consulting (Canada) Inc.	Tested By:	AMT
Address:		Page:	1 of 1

B.H. Number	Sample Number	Moisture Content (%)	Visual Description of Soil
14-SWC-968	MM-101259	16.6	
14-SWC-970	MM-101262	27.6	
14-SWC-969	MM-101270	10.7	
14-SWC-969	MM-101273	26.3	
14-SWC-972	MM-101277	16.5	
14-SWC-972	MM-101280	31.7	
14-SWC-973	MM-101285	35.9	
14-SWC-973	MM-101288	13.2	
14-SWC-975	MM-101298	28.1	
14-SWC-979	MM-101317	26.5	
14-SWC-980	MM-101326	18.8	
15-SWC-995	58554	13.4	
15-SWC-996	58557	14.8	
15-SWC-996	58558	21.7	
15-SWC-996	58559	16.1	
15-SWC-997	160025	10.3	
15-SWC-997	58565	13.7	
15-SWC-997	58568	11.7	
15-SWC-997	58570	15.4	
15-SWC-997	58572	12.7	

Reviewed By: ______________________ P.Eng.

TETRA TECH

FROZEN BULK RELATIVE DENSITY RESULTS

Project:	SRK Minto Samples - Feb. 2015 Lab Testing	Sample No.:	
Project No.:	W14103546-01	Date Tested:	27-Feb-15
Client:	SRK Consulting (Canada) Inc.	Tested By:	AMT
Address:		Page:	1 of 1

Bore Hole Number	Sample Number	Relative Density kg/m³	
15-SWC-997	160025	2317.63	
15-SWC-997	58568	2221.89	
15-SWC-997	58570	2224.24	
15-SWC-997	58572	2243.78	
15-SWC-997	58565	2353.06	
15-SWC-996	58557	2186.32	
15-SWC-996	58558	2026.10	
15-SWC-996	58559	2126.37	

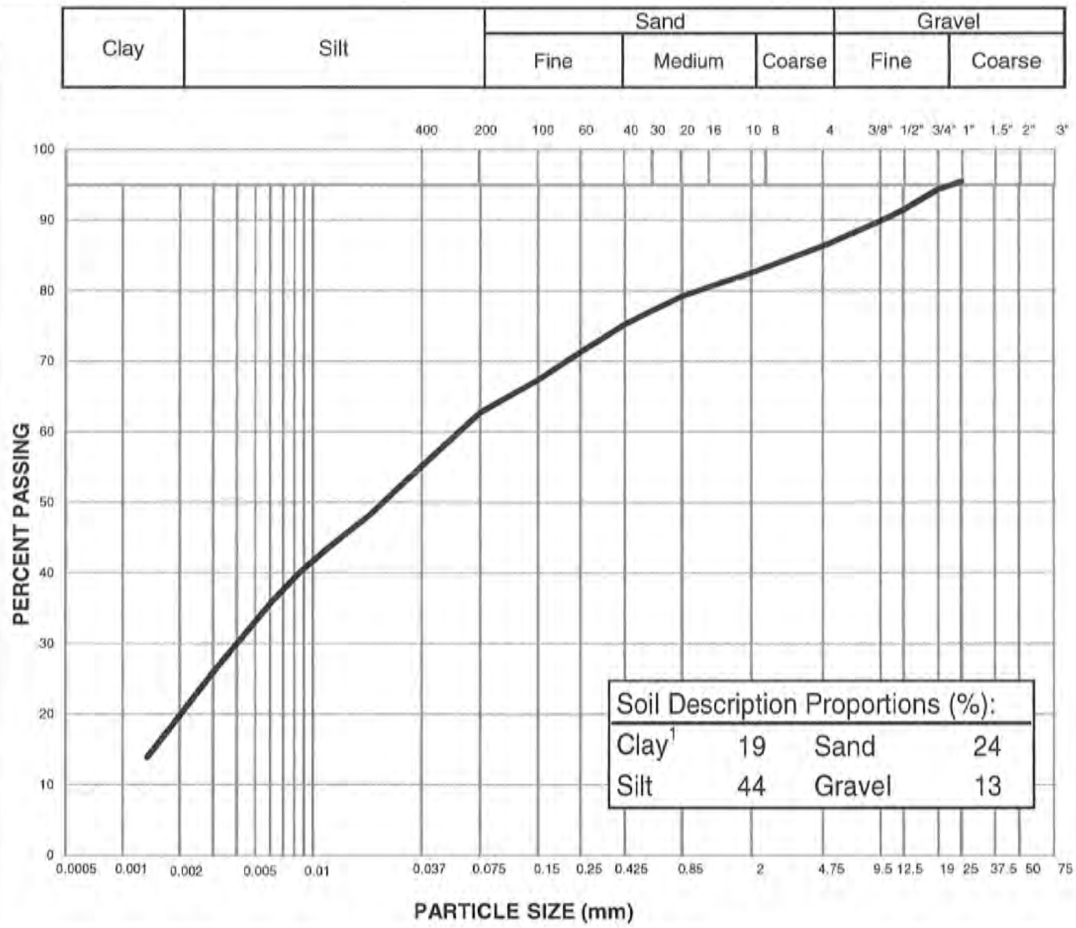
Reviewed By: ____________

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	MM-101259
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	14-SWC-968
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	15.05 - 15.40 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 5, 2015 By: AMT	Date sampled:	November 1, 2014
Soil Description[2]:	SILT - sandy, some clay, some gravel	Sampled By:	Client
		USC Classification:	Cu: #N/A
Moisture Content:	16.6%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
38	
25	95
19	94
12.5	91
10	90
5	87
2	83
0.85	79
0.425	75
0.25	71
0.15	67
0.075	62.7
0.0308	53.1
0.0199	48.2
0.0117	43.3
0.0085	40.0
0.0061	35.9
0.0030	26.1
0.0014	13.9



Soil Description Proportions (%):			
Clay[1]	19	Sand	24
Silt	44	Gravel	13

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification: ______

Remarks: ______

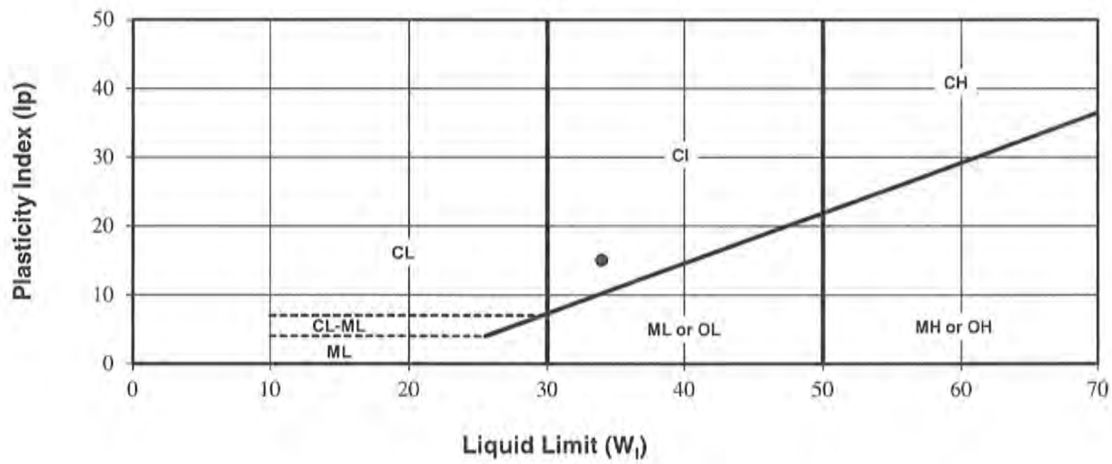
Reviewed By: ______ C.E.T.

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	MM-101259
		Borehole Number:	14-SWC-968
Project No:	W14103546-01	Depth:	15.05 - 15.40 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murrary McGregor	Date Sampled:	November 1, 2014
Email:		Date Tested:	March 6, 2015

Sample Description: SILT - sandy, some clay, some gravel



Liquid Limit (W_1):	34	Natural Moisture (%)	16.6
Plastic Limit :	19	Soil Plasticity:	Medium
Plasticity Index (Ip) :	**15**	Mod.USCS Symbol:	CI

Remarks:

Reviewed By: [signature] C.E.T.

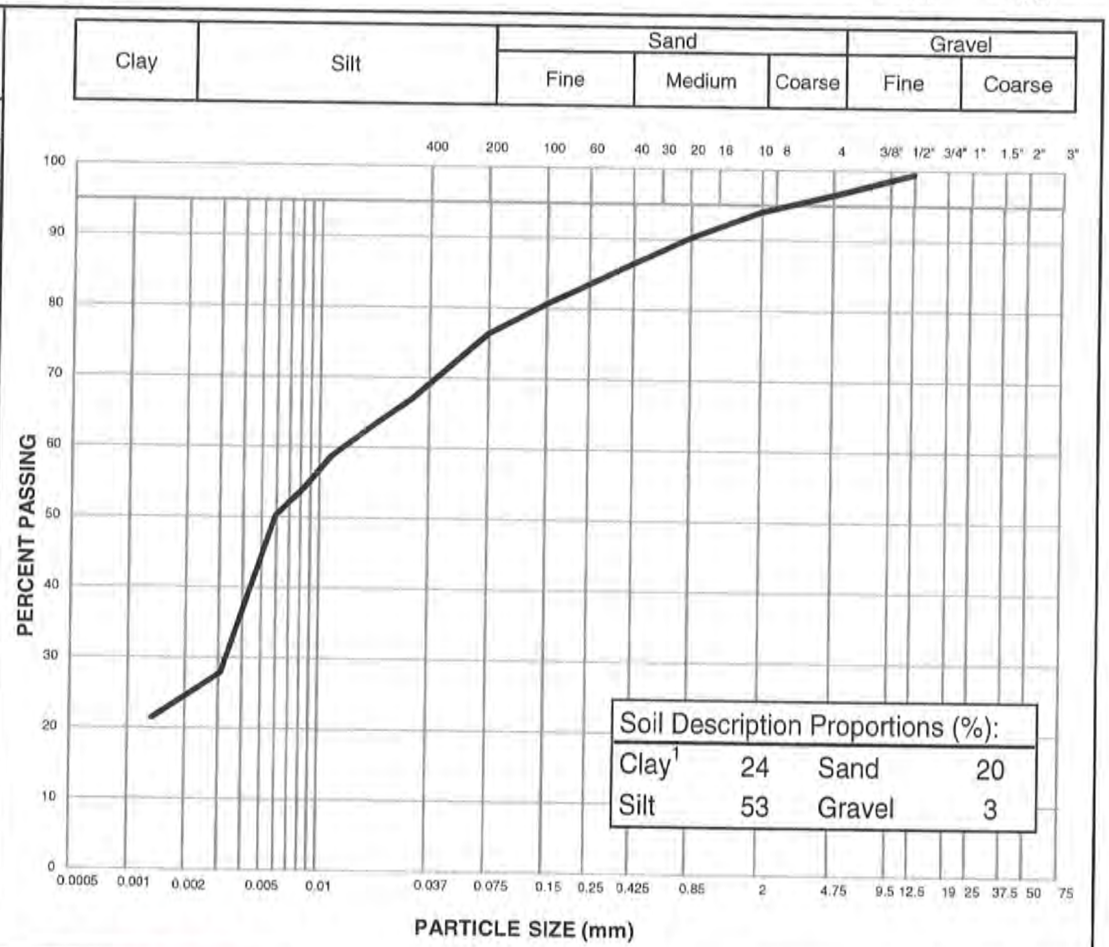
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	MM-101262
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	14-SWC-970
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	5.65 - 6.00 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 3, 2015 By: AMT	Date sampled:	November 2, 2014
Soil Description[2]:	SILT and CLAY - some sand, trace gravel	Sampled By:	Client
		USC Classification:	Cu: #N/A
Moisture Content:	27.6%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	
12.5	99
10	99
5	97
2	94
0.85	90
0.425	87
0.25	84
0.15	81
0.075	76.4
0.0303	67.0
0.0194	63.3
0.0114	58.7
0.0082	54.0
0.0059	50.3
0.0031	27.9
0.0013	21.4



Soil Description Proportions (%):			
Clay[1]	24	Sand	20
Silt	53	Gravel	3

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: _______________ C.E.T.

TETRA TECH

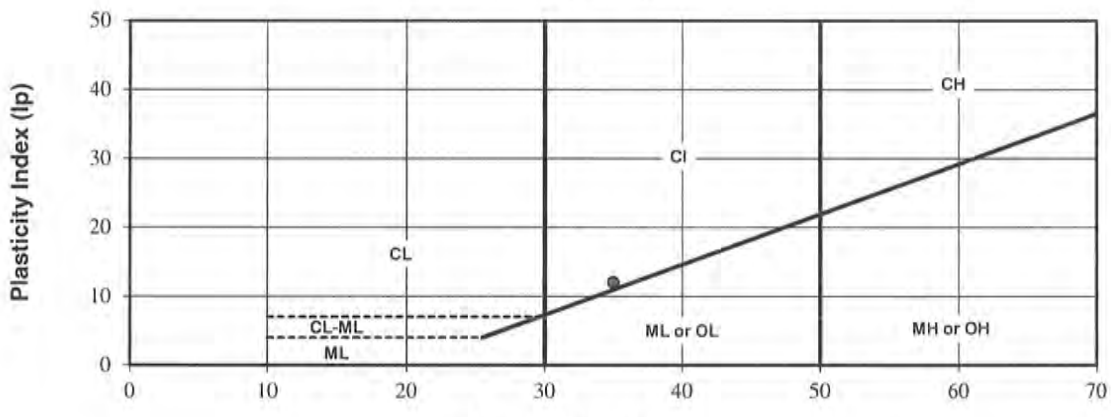
ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	MM-101262
		Borehole Number:	14-SWC-967
Project No:	W14103546-01	Depth:	5.65 - 6.00 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murrary McGregor	Date Sampled:	November 2, 2014
Email:		Date Tested:	March 6, 2015

Sample Description: SILT and CLAY - some sand, trace gravel

Plasticity Chart



Liquid Limit (W_1) :	35	Natural Moisture (%)	16.6
Plastic Limit :	23	Soil Plasticity:	Medium
Plasticity Index (Ip) :	**12**	Mod.USCS Symbol:	CI

Remarks:

Reviewed By: ____________ C.E.T.

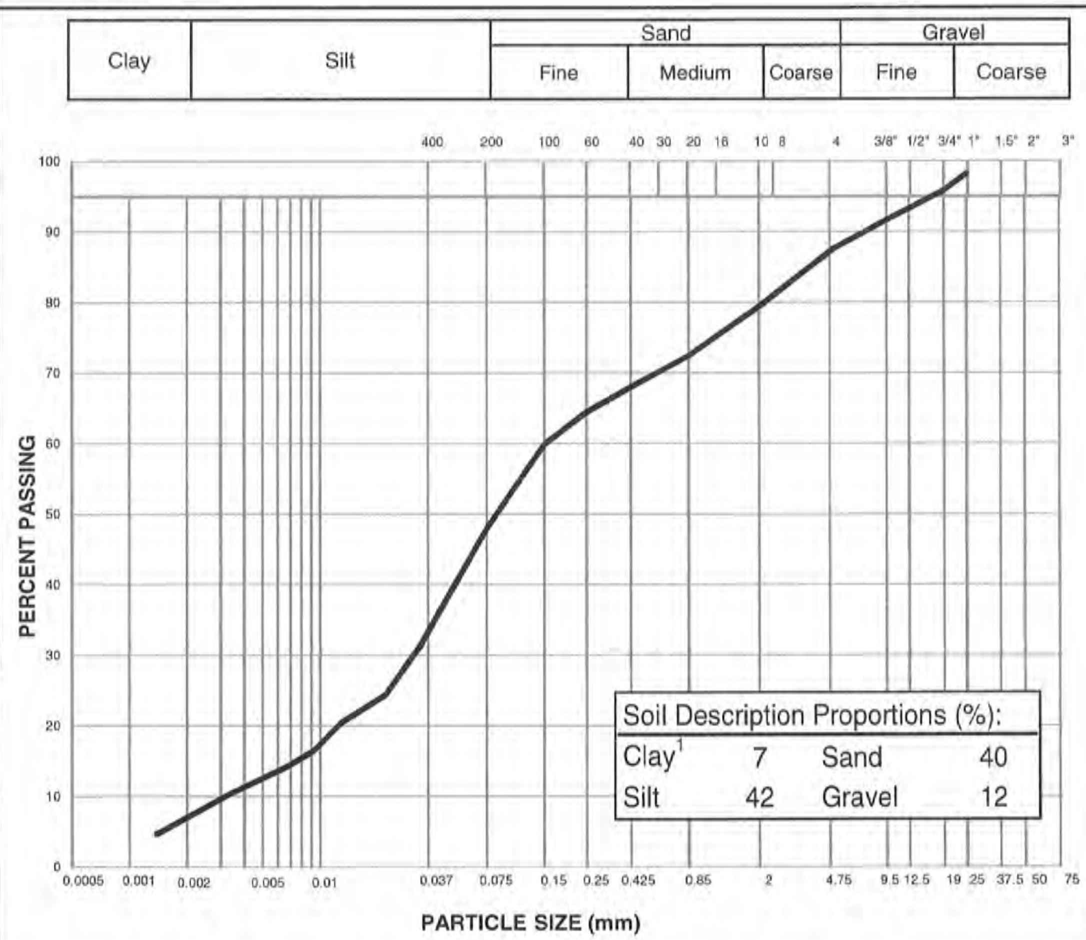
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	MM-101270
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	14-SWC-969
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	12.00 - 12.30 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 4, 2015 By: AMT	Date sampled:	November 2, 2014
Soil Description[2]:	SILT and SAND - some gravel, trace clay	Sampled By:	Client
		USC Classification:	Cu: 47.7
Moisture Content:	10.7%		Cc: 2.0

Particle Size (mm)	Percent Passing
75	
50	
38	
25	98
19	96
12.5	93
10	92
5	88
2	79
0.85	72
0.425	68
0.25	64
0.15	60
0.075	48.0
0.0339	31.4
0.0220	24.4
0.0129	20.4
0.0093	16.5
0.0066	14.1
0.0033	10.2
0.0014	4.7



Soil Description Proportions (%):			
Clay[1]	7	Sand	40
Silt	42	Gravel	12

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: ______________ C.E.T.

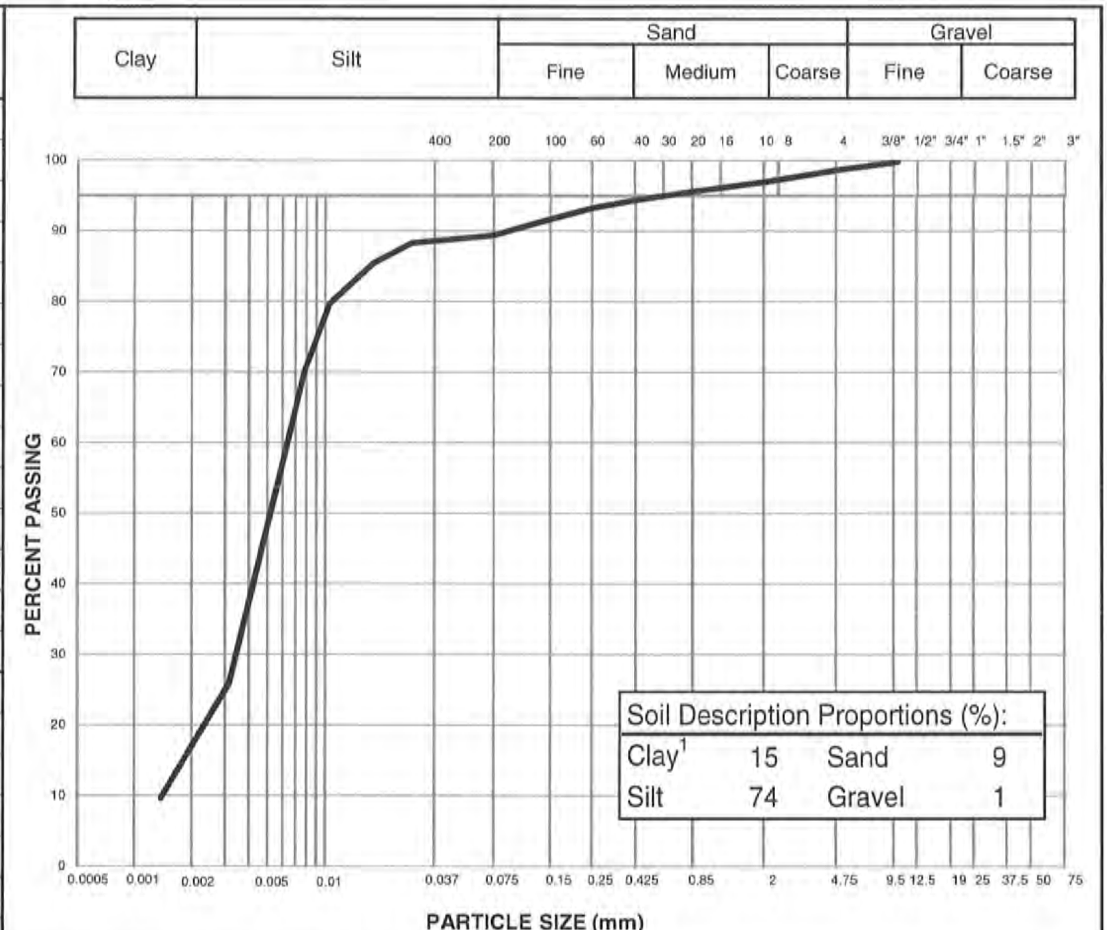
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	MM-101273
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	14-SWC-969
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	19.05 - 19.35 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 4, 2015 By: AMT	Date sampled:	November 2, 2014
Soil Description[2]:	SILT - some clay, trace sand, trace gravel	Sampled By:	Client
		USC Classification:	Cu: 4.5
Moisture Content:	26.3%		Cc: 1.4

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	
12.5	
10	100
5	99
2	97
0.85	96
0.425	94
0.25	93
0.15	92
0.075	89.4
0.0282	88.3
0.0178	85.4
0.0106	79.7
0.0078	70.1
0.0058	55.7
0.0032	25.9
0.0014	9.6



Soil Description Proportions (%):			
Clay[1]	15	Sand	9
Silt	74	Gravel	1

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

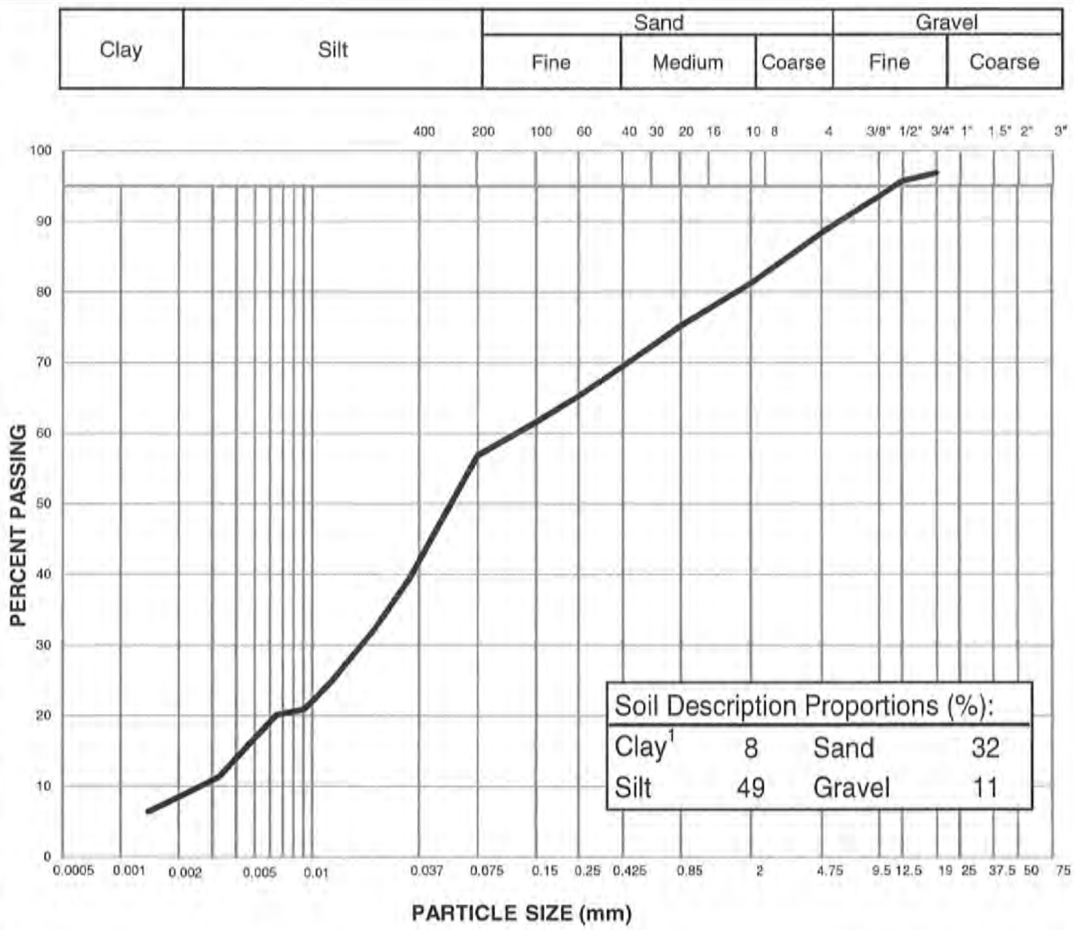
Reviewed By: ______________________ C.E.T.

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	MM-101277
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	14-SWC-972
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	9.25 - 9.55 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 3, 2015 By: AMT	Date sampled:	November 4, 2014
Soil Description[2]:	SILT - sandy, some gravel, trace clay	Sampled By:	Client
		USC Classification:	Cu: 45.3
Moisture Content:	16.6%		Cc: 1.0

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	97
12.5	96
10	94
5	89
2	81
0.85	75
0.425	70
0.25	65
0.15	62
0.075	56.9
0.0329	39.4
0.0214	32.2
0.0127	24.9
0.0091	20.9
0.0065	20.1
0.0032	11.3
0.0014	6.4



Soil Description Proportions (%):			
Clay[1]	8	Sand	32
Silt	49	Gravel	11

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: ______________ C.E.T.

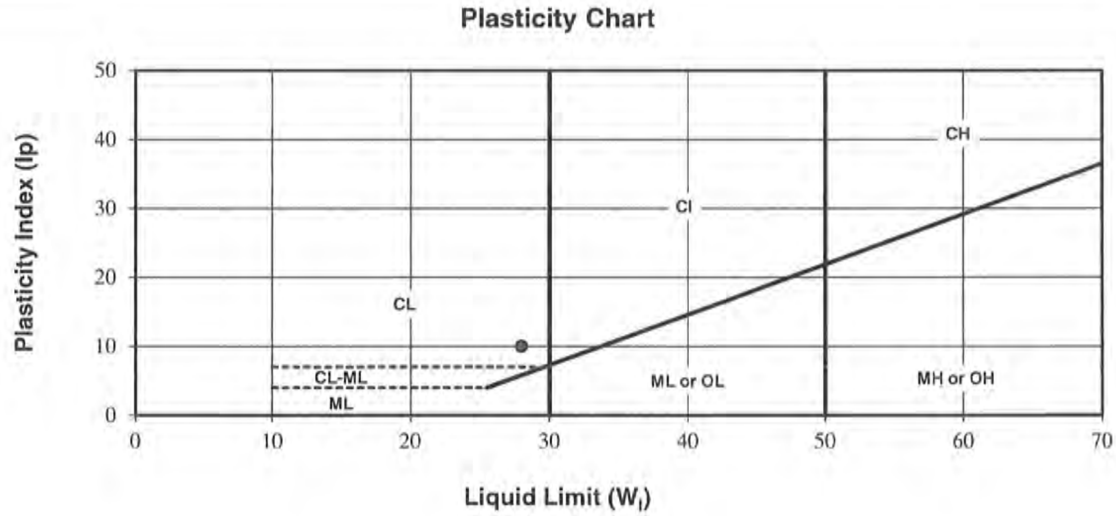
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	MM-101277
		Borehole Number:	14-SWC-272
Project No:	W14103546-01	Depth:	9.25 - 9.55 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murray McGregor	Date Sampled:	November 4, 2014
Email:		Date Tested:	March 5, 2015

Sample Description: SILT - sandy, some gravel, trace clay



Liquid Limit ($W_{1)}$:	28	Natural Moisture (%)	16.6
Plastic Limit :	18	Soil Plasticity:	Low to Medium
Plasticity Index (Ip) :	**10**	Mod.USCS Symbol:	CL-CI

Remarks:

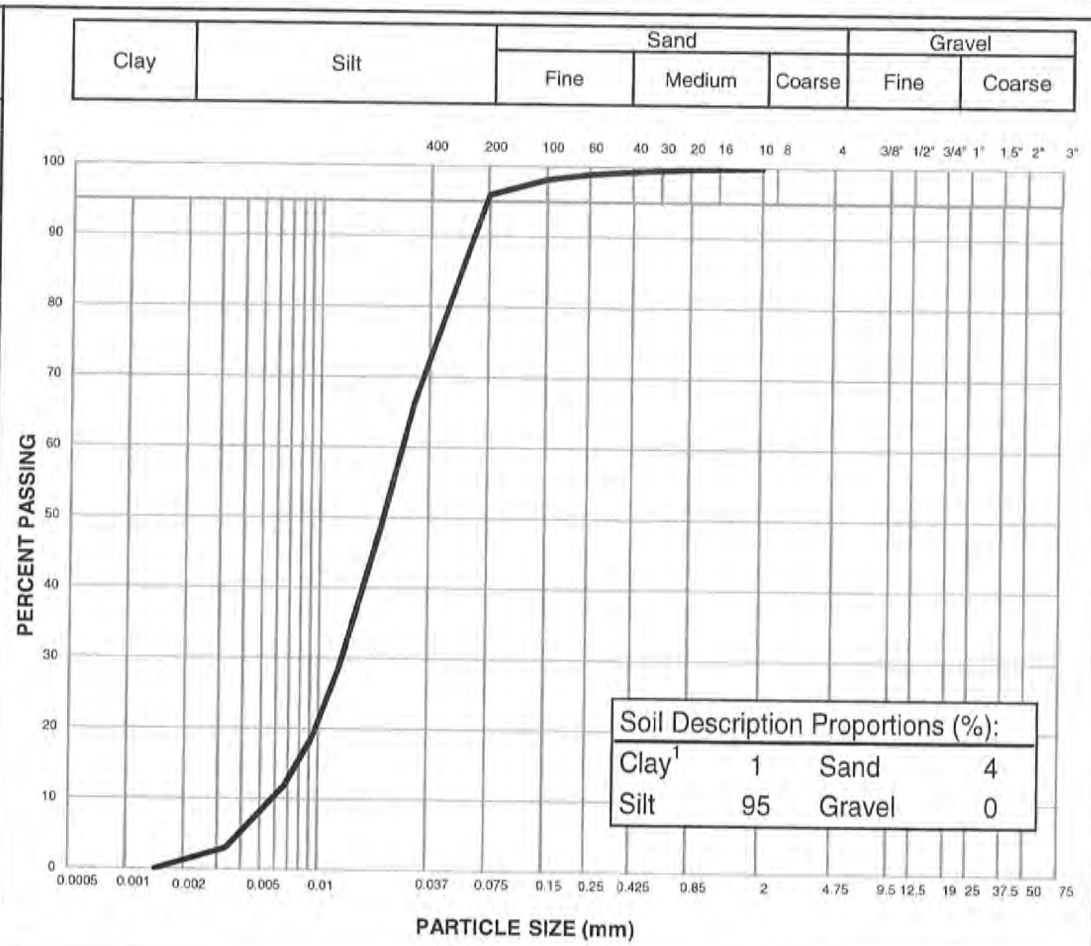
Reviewed By: [signature] C.E.T.

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	MM-101280
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	14-SWC-972
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	18.55 - 18.85 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 3, 2015 By: AMT	Date sampled:	November 4, 2014
Soil Description[2]:	SILT - trace sand, trace clay	Sampled By:	Client
		USC Classification:	Cu: 4.6
Moisture Content:	31.7%		Cc: 1.1

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	
12.5	
10	
5	
2	100
0.85	100
0.425	99
0.25	99
0.15	98
0.075	96.0
0.0309	66.3
0.0208	48.5
0.0128	28.7
0.0093	18.8
0.0067	11.9
0.0033	3.0
0.0014	0.0



Soil Description Proportions (%):			
Clay[1]	1	Sand	4
Silt	95	Gravel	0

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual
[2] The description is visually based & subject to EBA description protocols

Specification: ______

Remarks: ______

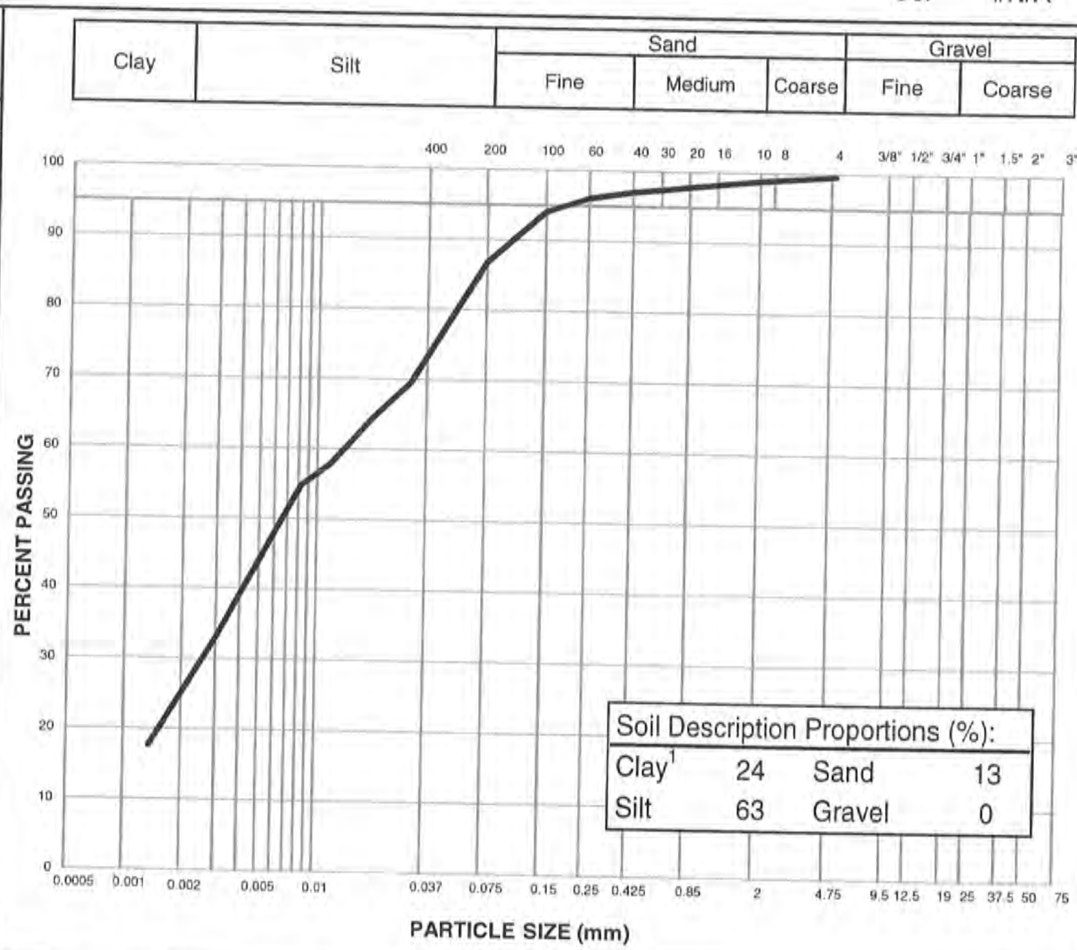
Reviewed By: ______ C.E.T.

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	MM-101285
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	14-SWC-973
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	2.80 - 3.10 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 3, 2015 By: AMT	Date sampled:	November 6, 2014
Soil Description[2]:	SILT and CLAY - some sand	Sampled By:	Client
		USC Classification:	Cu: #N/A
Moisture Content:	35.9%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	
12.5	
10	
5	100
2	99
0.85	98
0.425	97
0.25	96
0.15	94
0.075	86.8
0.0304	69.5
0.0196	64.6
0.0116	57.7
0.0083	54.8
0.0060	47.9
0.0030	33.3
0.0014	17.6



Soil Description Proportions (%):			
Clay[1]	24	Sand	13
Silt	63	Gravel	0

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: C.E.T.

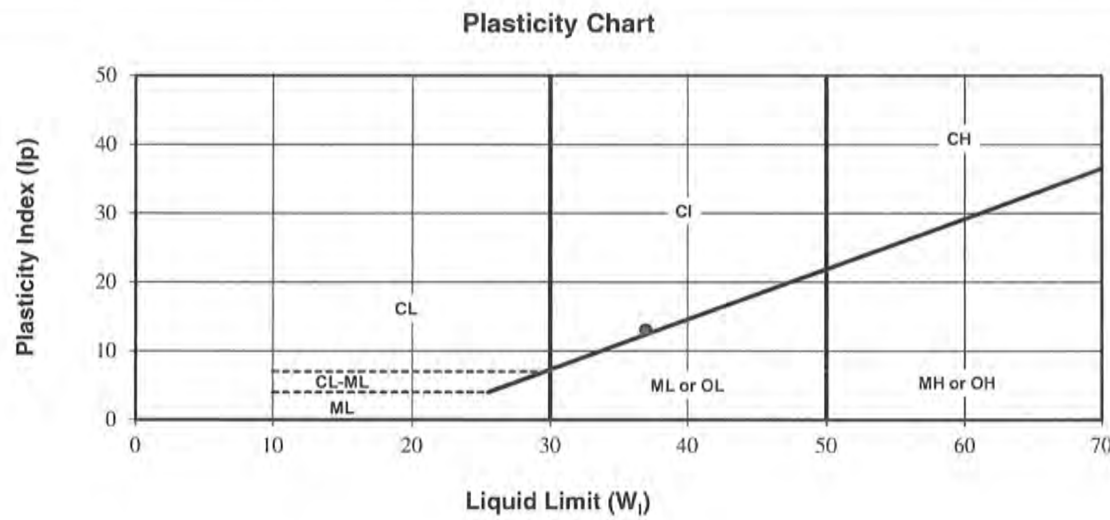
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	MM-101285
		Borehole Number:	14-SWC-973
Project No:	W14103546-01	Depth:	2.80 - 3.10 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murray McGregor	Date Sampled:	November 6, 2014
Email:		Date Tested:	March 5, 2015

Sample Description: SILT and CLAY - some sand



Liquid Limit ($W_{1)}$:	37	Natural Moisture (%)	35.9
Plastic Limit :	24	Soil Plasticity:	Medium
Plasticity Index (Ip) :	**13**	Mod.USCS Symbol:	CI

Remarks:

Reviewed By: _______________ C.E.T.

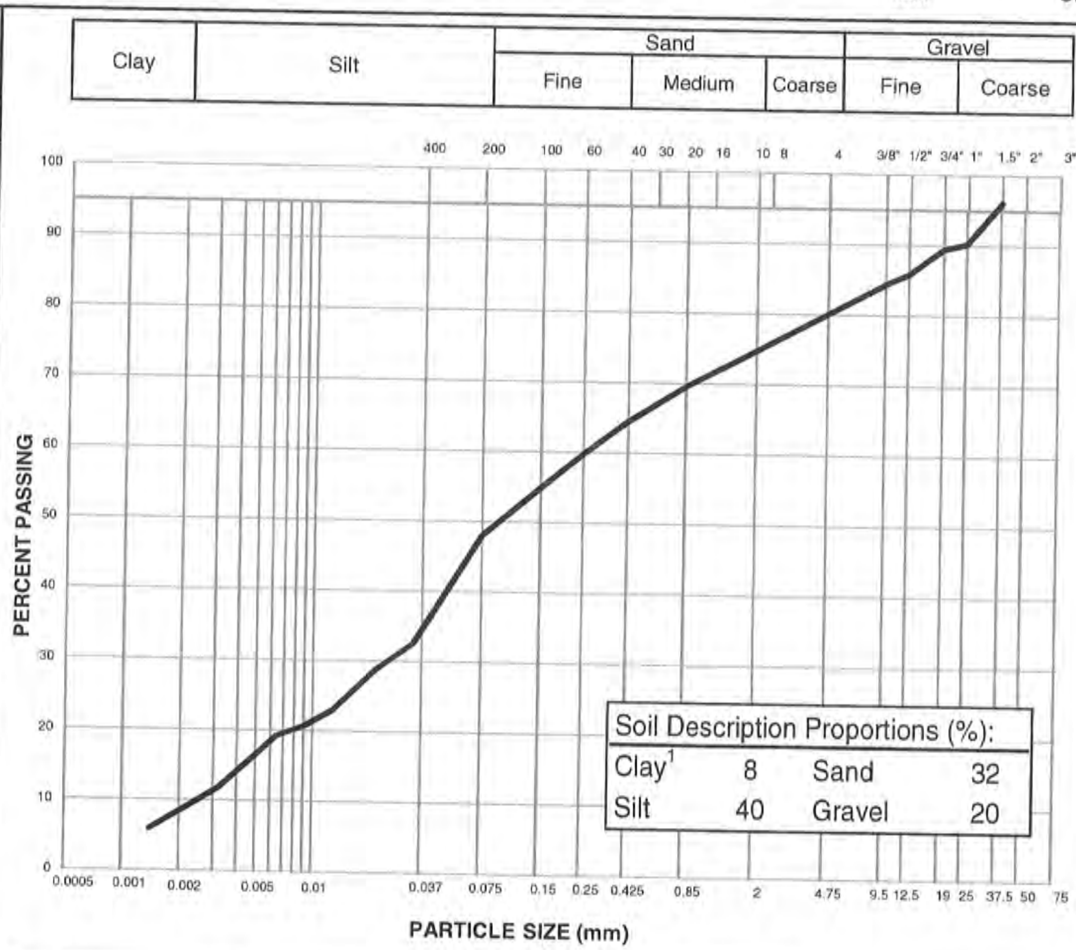
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	MM-101288
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	14-SWC-973
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	9.17 - 9.47 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 3, 2015 By: AMT	Date sampled:	November 6, 2014
Soil Description[2]:	SILT - sandy, some gravel, trace clay	Sampled By:	Client
		USC Classification:	Cu: 97.2
Moisture Content:	13.2%		Cc: 0.9

Particle Size (mm)	Percent Passing
75	
50	
38	96
25	90
19	89
12.5	86
10	85
5	80
2	75
0.85	70
0.425	64
0.25	60
0.15	55
0.075	48.0
0.0335	32.6
0.0215	28.9
0.0127	22.9
0.0091	20.7
0.0065	19.2
0.0032	11.8
0.0014	5.9



Soil Description Proportions (%):			
Clay[1]	8	Sand	32
Silt	40	Gravel	20

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: _______________ C.E.T.

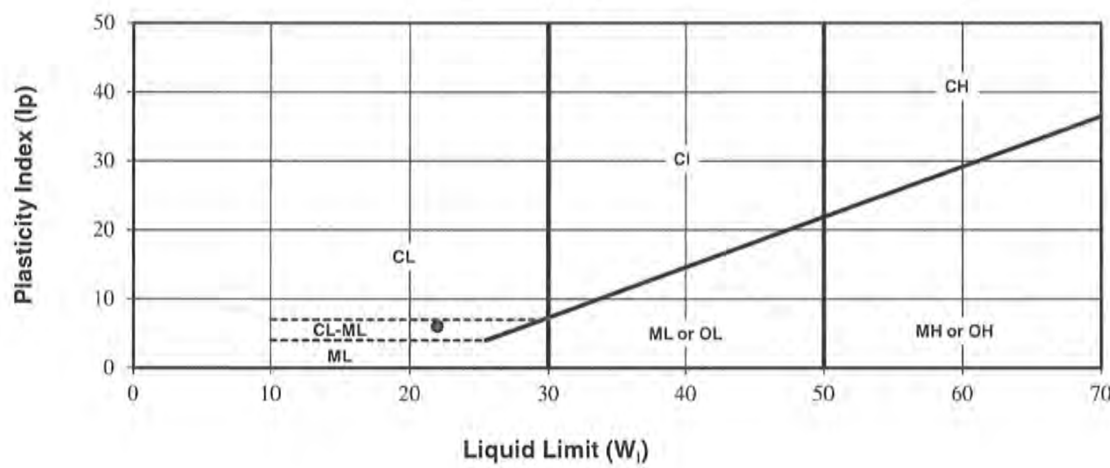
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	MM-101288
		Borehole Number:	14-SWC-973
Project No:	W14103546-01	Depth:	9.17 - 9.47 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murrary McGregor	Date Sampled:	November 6, 2014
Email:		Date Tested:	March 5, 2015

Sample Description: SILT - sandy, some gravel, trace silt



Liquid Limit (W_1):	22	Natural Moisture (%)	35.9
Plastic Limit :	16	Soil Plasticity:	Low
Plasticity Index (Ip) :	**6**	Mod.USCS Symbol:	CL-ML

Remarks:

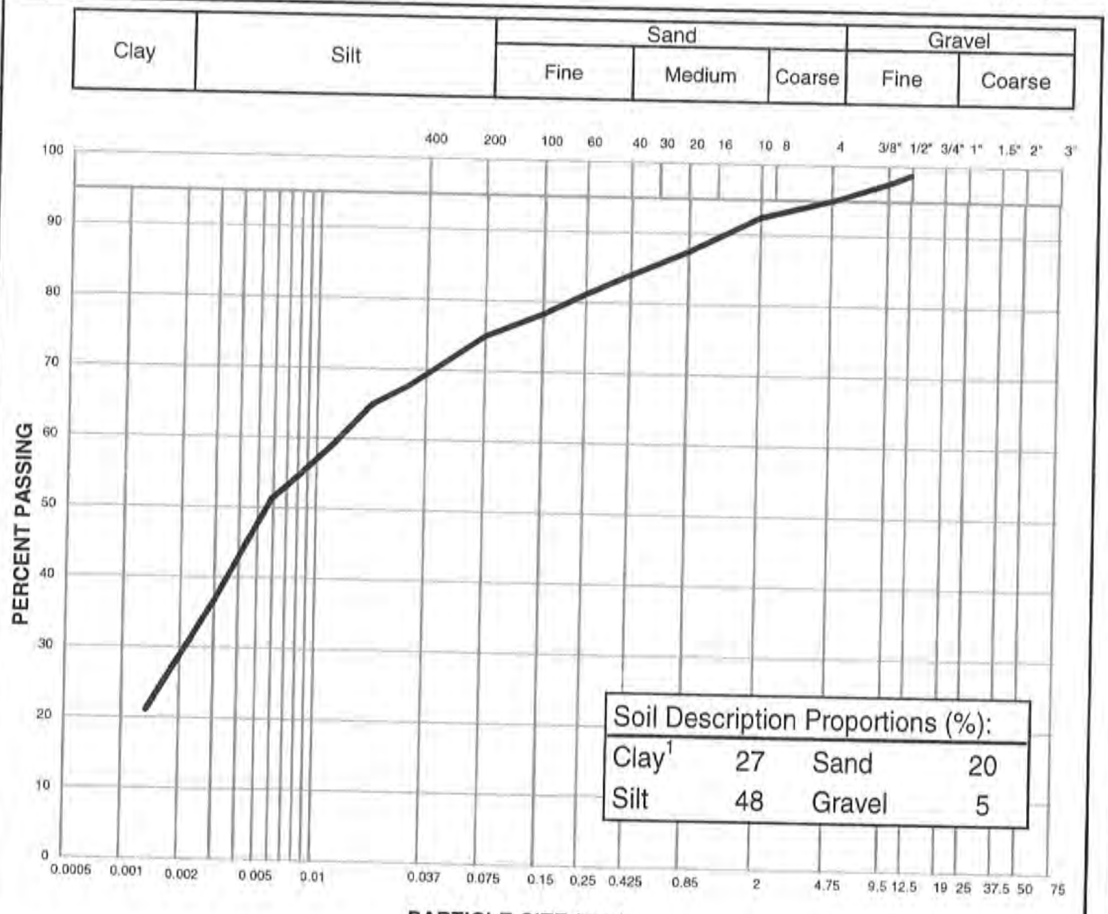
Reviewed By: [signature] C.E.T.

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	MM-101298
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	14-SWC-975
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	5.70 - 6.00 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 3, 2015 By: AMT	Date sampled:	November 9, 2014
Soil Description[2]:	SILT and CLAY - some sand, trace gravel	Sampled By:	Client
		USC Classification:	Cu: #N/A
Moisture Content:	28.1%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	
12.5	99
10	98
5	95
2	92
0.85	87
0.425	84
0.25	81
0.15	78
0.075	74.9
0.0304	67.8
0.0195	65.0
0.0116	58.6
0.0083	54.9
0.0059	51.3
0.0030	36.6
0.0013	21.1



Soil Description Proportions (%):			
Clay[1]	27	Sand	20
Silt	48	Gravel	5

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual
[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: C.E.T.

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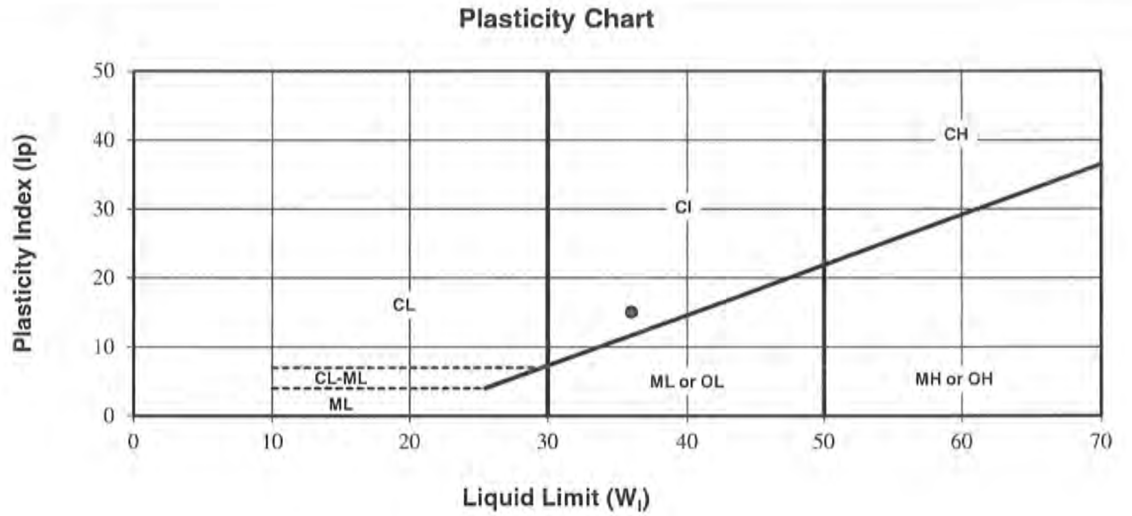
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	MM-101298
		Borehole Number:	14-SWC-975
Project No:	W14103546-01	Depth:	5.70 - 6.00 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murrary McGregor	Date Sampled:	November 9, 2014
Email:		Date Tested:	March 5, 2015

Sample Description: SILT and CLAY - some sand, trace gravel



Liquid Limit ($W_{1)}$) :	36	Natural Moisture (%)	35.9
Plastic Limit :	21	Soil Plasticity:	Medium
Plasticity Index (Ip) :	**15**	Mod.USCS Symbol:	CI

Remarks:

Reviewed By: [signature] C.E.T.

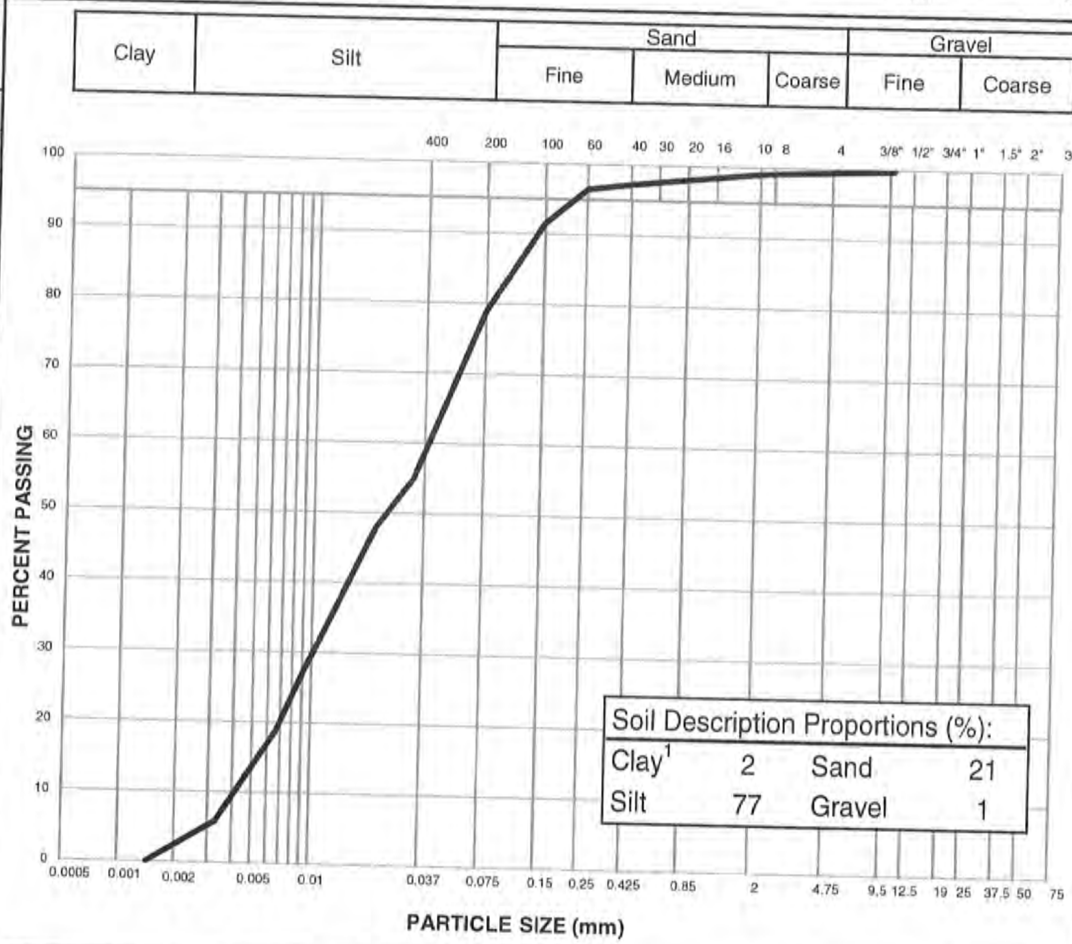
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	MM-101317
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	14-SWC-979
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	20.60 - 20.90 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 3, 2015 By: AMT	Date sampled:	November 9, 2014
Soil Description[2]:	SILT - sandy, trace clay, trace gravel	Sampled By:	Client
		USC Classification:	Cu: 9.5
Moisture Content:	26.5%		Cc: 0.6

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	
12.5	
10	100
5	100
2	99
0.85	98
0.425	97
0.25	96
0.15	92
0.075	78.9
0.0325	54.9
0.0211	48.1
0.0127	35.3
0.0092	27.5
0.0066	18.6
0.0033	5.9
0.0014	0.0



Soil Description Proportions (%):			
Clay[1]	2	Sand	21
Silt	77	Gravel	1

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: ______________________ C.E.T.

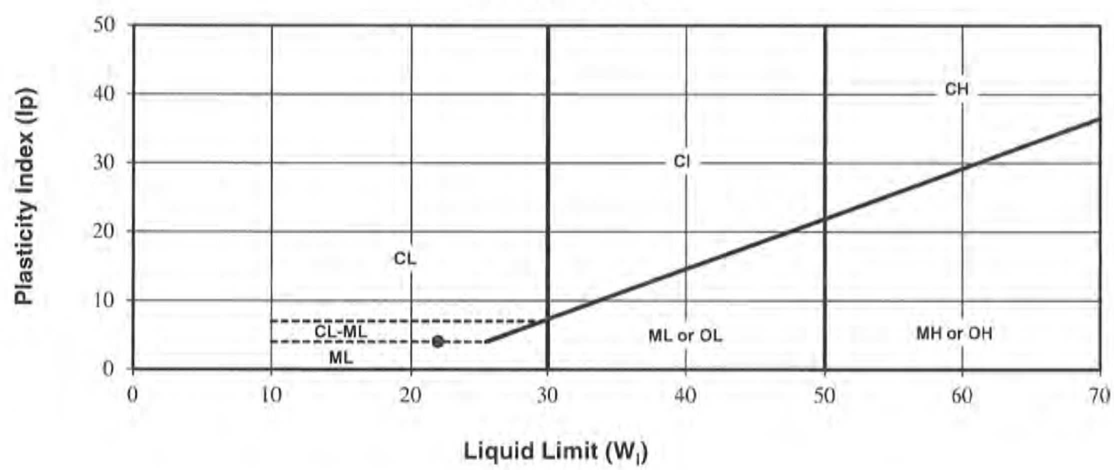
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	MM-101317
		Borehole Number:	14-SWC-979
Project No:	W14103546-01	Depth:	20.60 - 20.90 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murrary McGregor	Date Sampled:	November 9, 2014
Email:		Date Tested:	March 5, 2015

Sample Description: SILT - sandy, trace clay, trace gravel



Liquid Limit (W_1) :	22	Natural Moisture (%)	35.9
Plastic Limit :	18	Soil Plasticity:	Low
Plasticity Index (Ip) :	4	Mod.USCS Symbol:	CL-ML

Remarks:

Reviewed By: ______________ C.E.T.

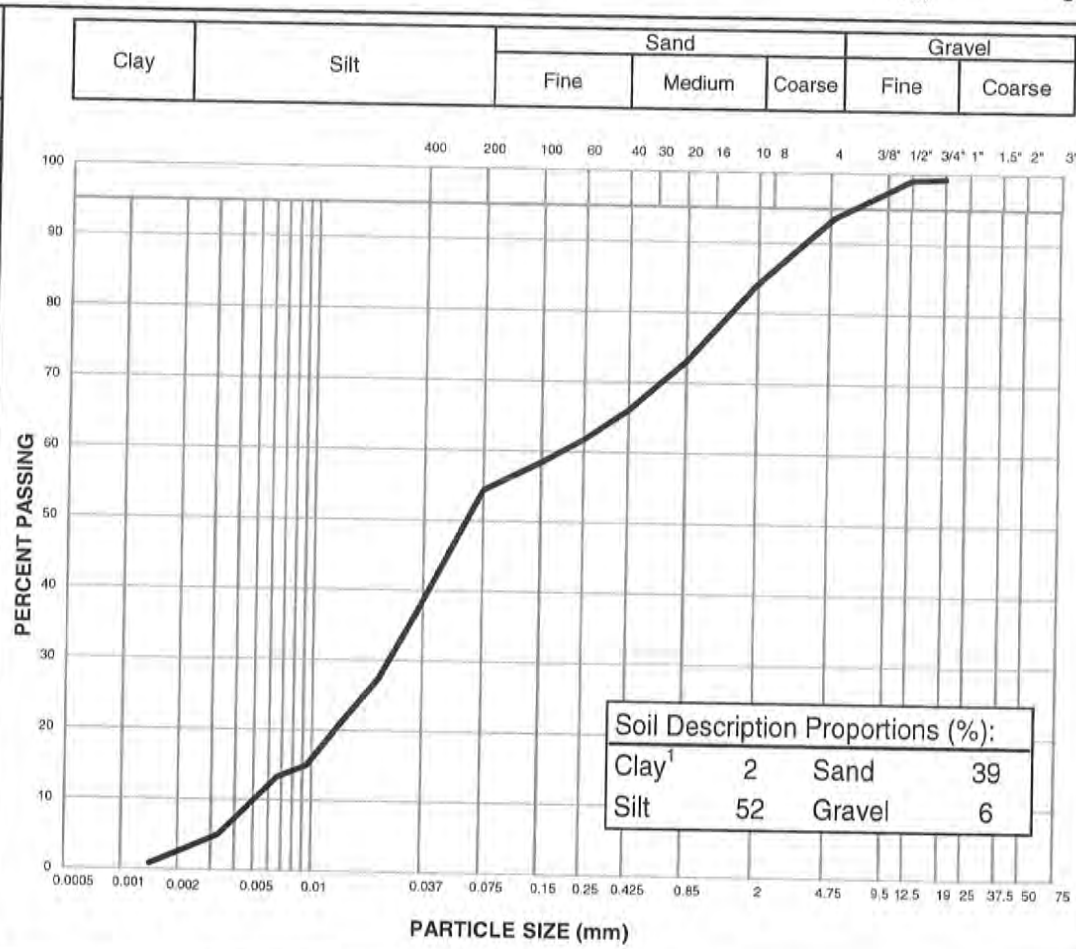
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	MM-101326
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	14-SWC-980
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	19.40 - 19.70 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 3, 2015 By: AMT	Date sampled:	November 9, 2014
Soil Description[2]:	SILT and SAND - trace gravel, trace clay	Sampled By:	Client
Moisture Content:	18.8%	USC Classification:	Cu: 37.1 / Cc: 0.6

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	99
12.5	99
10	98
5	94
2	84
0.85	73
0.425	66
0.25	62
0.15	58
0.075	54.4
0.0339	36.7
0.0222	27.5
0.0131	20.0
0.0094	15.0
0.0066	13.3
0.0033	5.0
0.0014	0.8



Soil Description Proportions (%):			
Clay[1]	2	Sand	39
Silt	52	Gravel	6

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: ____________ C.E.T.

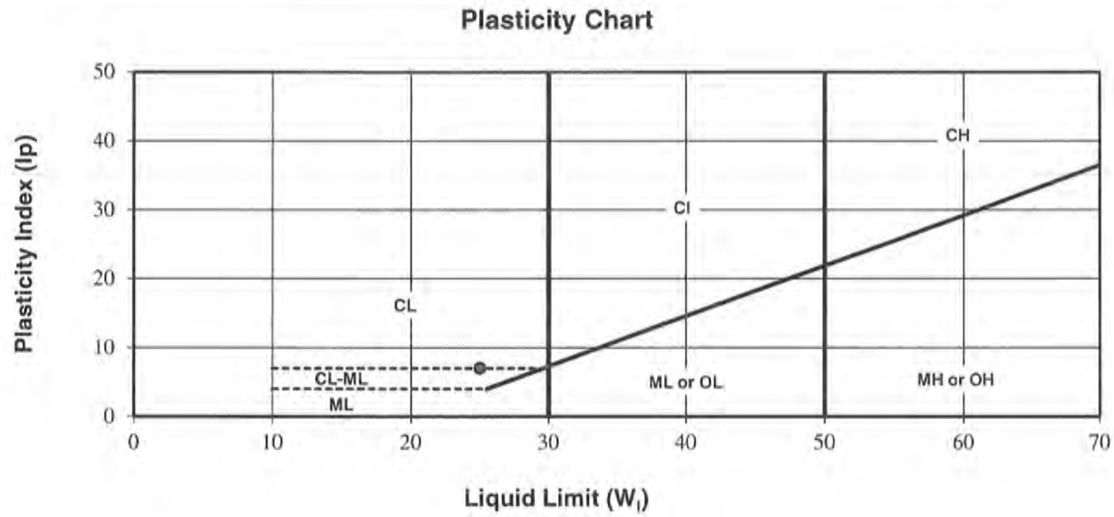
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	MM-101326
		Borehole Number:	14-SWC-980
Project No:	W14103546-01	Depth:	19.40 - 19.70 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murrary McGregor	Date Sampled:	November 9, 2014
Email:		Date Tested:	March 5, 2015

Sample Description: SILT and SAND - trace gravel, trace clay



Liquid Limit (W_1) :	25	Natural Moisture (%)	35.9
Plastic Limit :	18	Soil Plasticity:	Low
Plasticity Index (Ip) :	**7**	Mod.USCS Symbol:	CL-ML

Remarks:

Reviewed By: ____________ C.E.T.

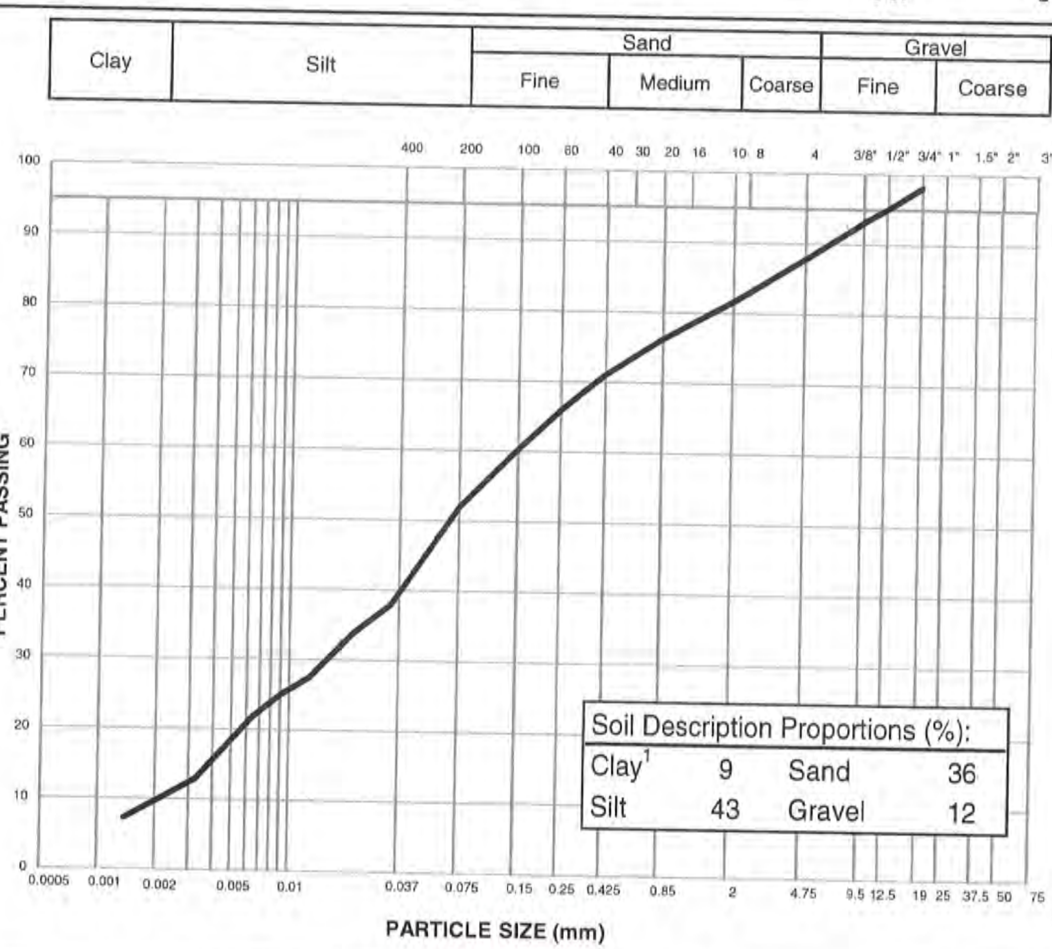
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	58554
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	15-SWC-995
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	8.60 - 8.90 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 4, 2015 By: AMT	Date sampled:	February 9, 2015
Soil Description[2]:	SILT and SAND - some gravel, trace clay	Sampled By:	Client
		USC Classification:	Cu: 64.8
Moisture Content:	13.4%		Cc: 0.8

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	98
12.5	95
10	94
5	88
2	82
0.85	76
0.425	71
0.25	66
0.15	60
0.075	51.9
0.0335	38.0
0.0216	33.9
0.0128	27.5
0.0091	25.0
0.0064	21.8
0.0033	12.9
0.0014	7.3



Soil Description Proportions (%):			
Clay[1]	9	Sand	36
Silt	43	Gravel	12

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: ____________ C.E.T.

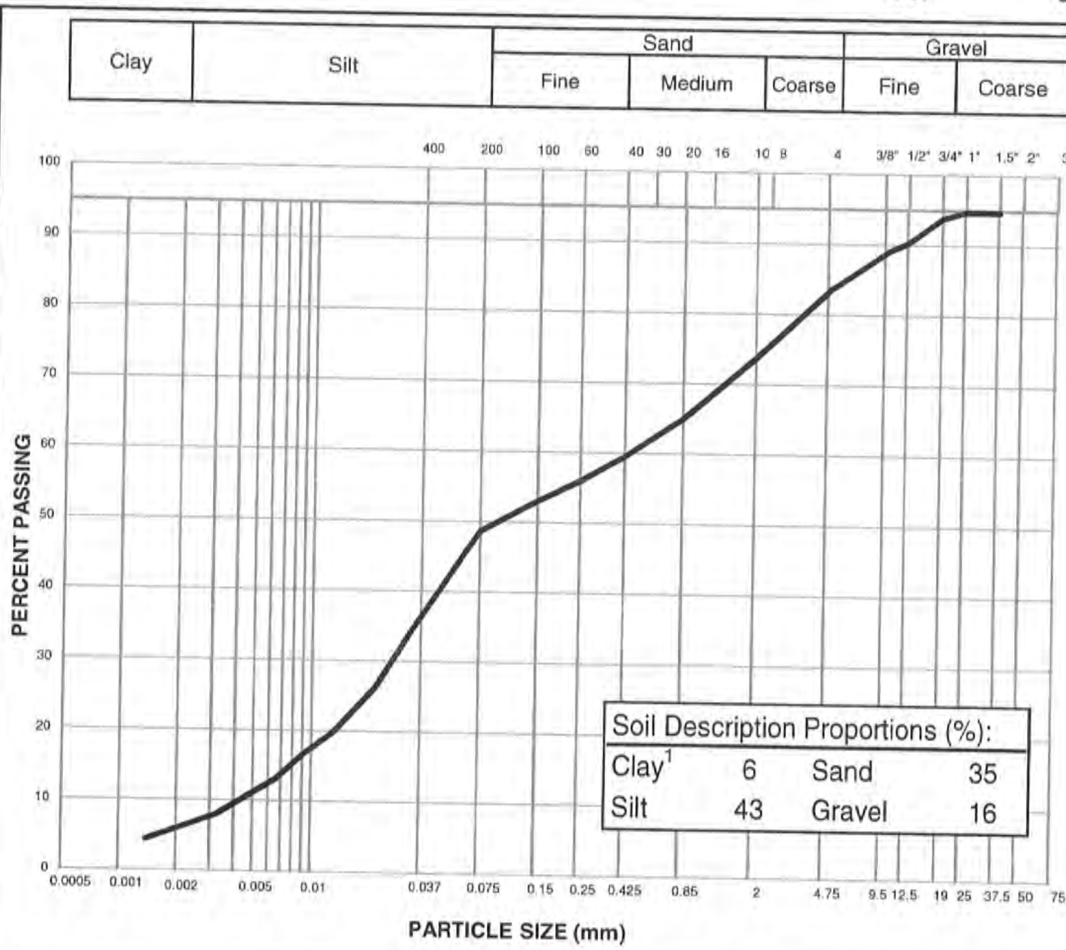
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	58557
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	15-SWC-996
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	6.12 - 6.42 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 4, 2015 By: AMT	Date sampled:	February 9, 2015
Soil Description[2]:	SILT - sandy, some gravel, trace clay	Sampled By:	Client
		USC Classification:	Cu: 101.8
Moisture Content:	14.8%		Cc: 0.3

Particle Size (mm)	Percent Passing
75	
50	
38	95
25	95
19	94
12.5	90
10	89
5	84
2	74
0.85	65
0.425	60
0.25	56
0.15	53
0.075	48.6
0.0327	34.3
0.0214	26.2
0.0129	19.7
0.0092	16.8
0.0066	13.1
0.0033	8.0
0.0014	4.4



Soil Description Proportions (%):			
Clay[1]	6	Sand	35
Silt	43	Gravel	16

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: ____________________ C.E.T.

TETRA TECH

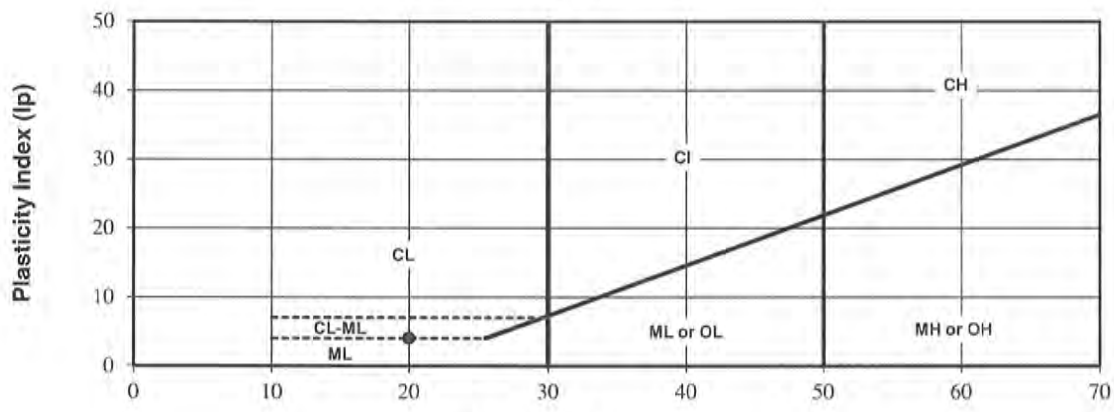
ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	58557
		Borehole Number:	15-SWC-996
Project No:	W14103546-01	Depth:	6.12 - 6.42 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murray McGregor	Date Sampled:	February 9, 2015
Email:		Date Tested:	March 6, 2015

Sample Description: SILT - sandy, some gravel, trace clay

Plasticity Chart



Liquid Limit ($W_{1)}$):	20	Natural Moisture (%)	35.9
Plastic Limit :	16	Soil Plasticity:	Low
Plasticity Index (Ip) :	4	Mod.USCS Symbol:	CL-ML

Remarks:

Reviewed By: [signature] C.E.T.

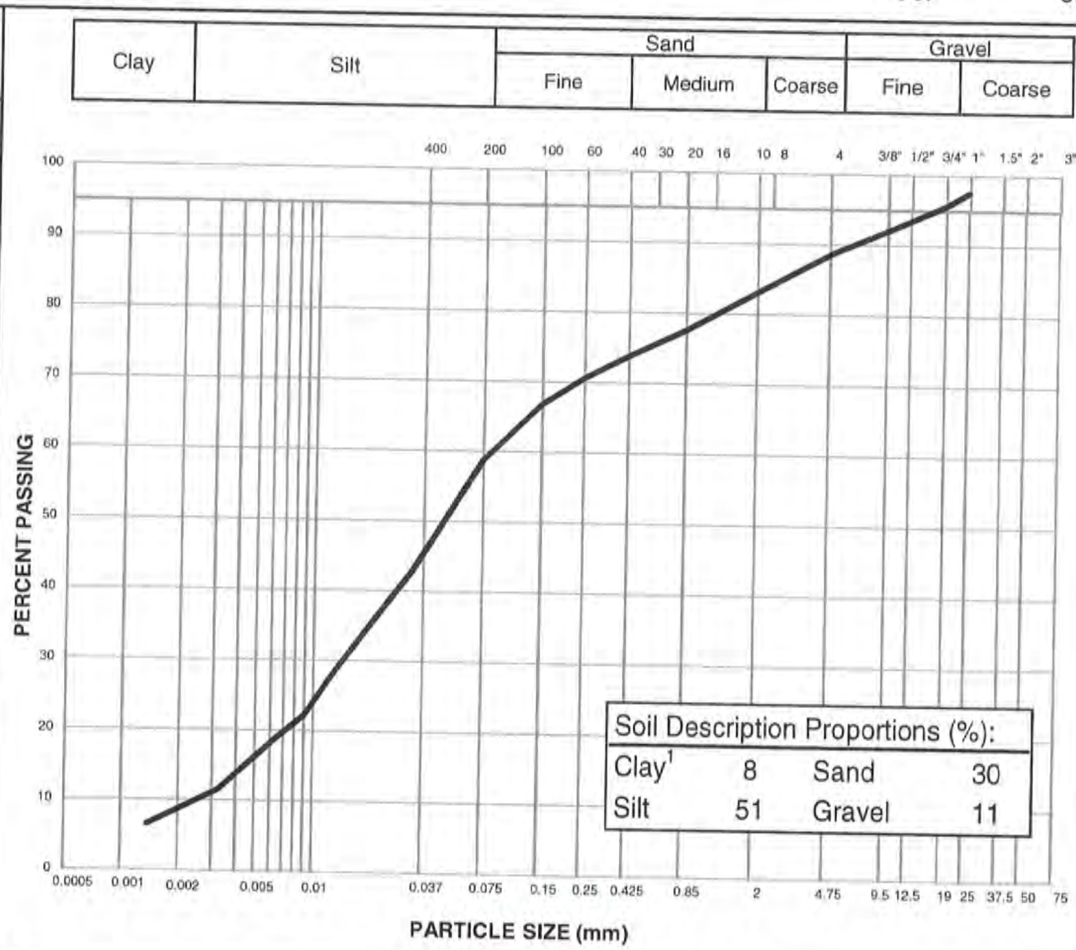
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	58559
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	15-SWC-996
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	14.73 - 15.10 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 5, 2015 By: AMT	Date sampled:	February 9, 2015
Soil Description[2]:	SILT - sandy, some gravel, trace clay	Sampled By:	Client
		USC Classification:	Cu: 32.3
Moisture Content:	16.1%		Cc: 0.9

Particle Size (mm)	Percent Passing
75	
50	
38	
25	98
19	96
12.5	94
10	92
5	89
2	83
0.85	78
0.425	74
0.25	71
0.15	67
0.075	58.8
0.0321	42.8
0.0209	36.2
0.0124	28.0
0.0090	22.2
0.0064	18.9
0.0032	11.5
0.0014	6.6



Soil Description Proportions (%):			
Clay[1]	8	Sand	30
Silt	51	Gravel	11

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: [signature] C.E.T.

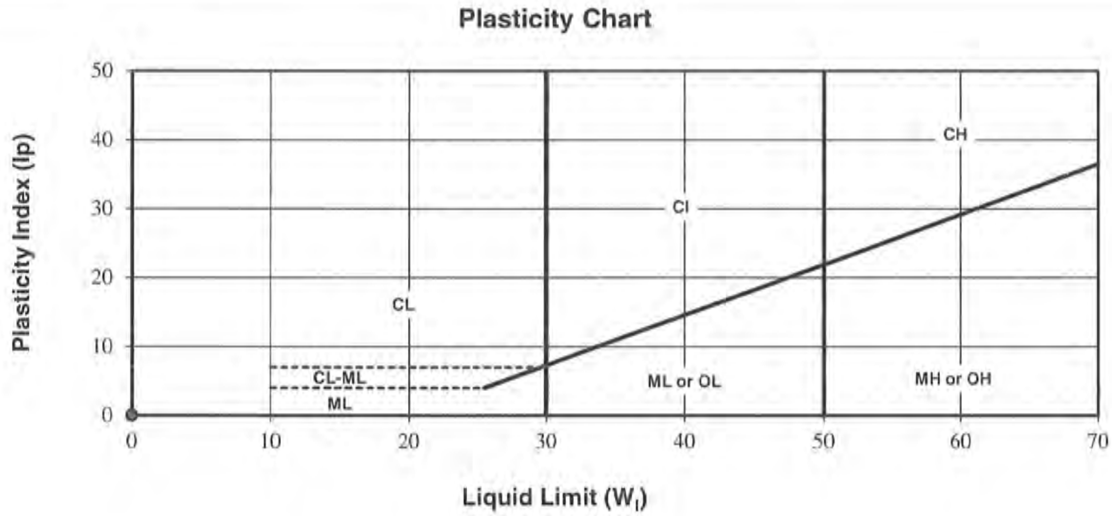
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	58559
		Borehole Number:	15-SWC-996
Project No:	W14103546-01	Depth:	14.73 - 15.10 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murrary McGregor	Date Sampled:	February 9, 2015
Email:		Date Tested:	March 6, 2015

Sample Description: SILT - sandy, some gravel, trace clay



Liquid Limit (W_1) :	0	Natural Moisture (%)	35.9
Plastic Limit :	0	Soil Plasticity:	NP
Plasticity Index (Ip) :	**0**	Mod.USCS Symbol:	N/A

Remarks: An atterberg was attempted and material was found to be non-plastic.

Reviewed By: ______________ C.E.T.

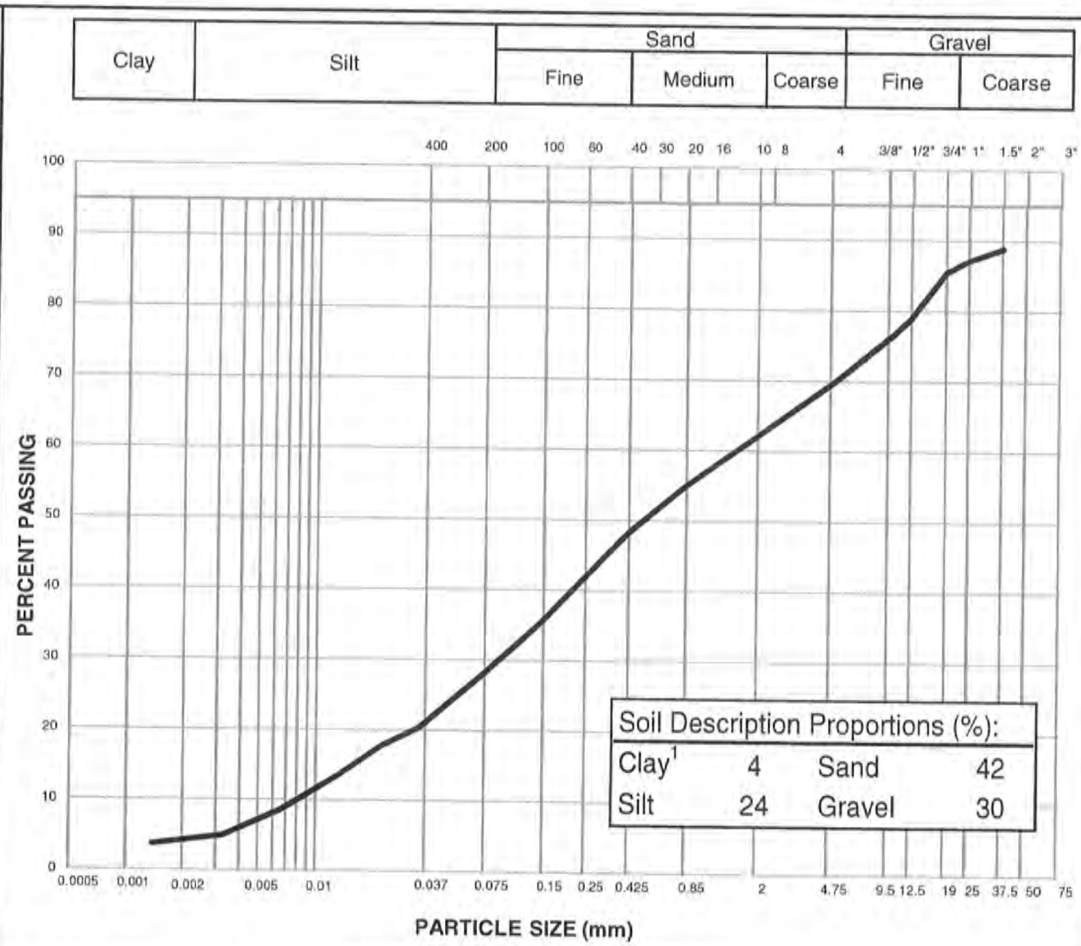
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	160025
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	15-SWC-997
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	9.79 - 10.11 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 5, 2015 By: AMT	Date sampled:	February 9, 2015
Soil Description[2]:	SAND - gravelley, silty, trace clay	Sampled By:	Client
		USC Classification:	Cu: 203.9
Moisture Content:	10.3%		Cc: 0.6

Particle Size (mm)	Percent Passing
75	
50	
38	89
25	87
19	85
12.5	79
10	76
5	70
2	62
0.85	55
0.425	48
0.25	42
0.15	36
0.075	28.2
0.0342	20.3
0.0221	17.8
0.0131	13.5
0.0093	11.1
0.0066	8.6
0.0033	4.9
0.0014	3.7



Soil Description Proportions (%):			
Clay[1]	4	Sand	42
Silt	24	Gravel	30

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: _______________ C.E.T.

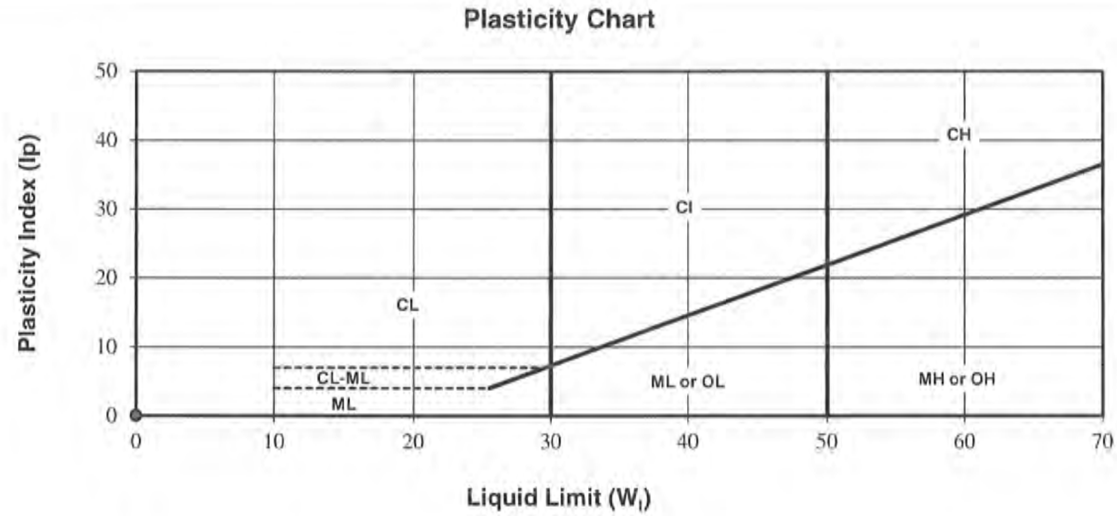
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	160025
		Borehole Number:	15-SWC-997
Project No:	W14103546-01	Depth:	9.79 - 10.11 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murrary McGregor	Date Sampled:	February 9, 2015
Email:		Date Tested:	March 5, 2015

Sample Description: SAND - gravelley, silty, trace clay



Liquid Limit (W_1) :	0	Natural Moisture (%)	35.9
Plastic Limit :	0	Soil Plasticity:	NP
Plasticity Index (Ip) :	**0**	Mod.USCS Symbol:	N/A

Remarks: An atterberg was attempted and material was found to be non-plastic.

Reviewed By: ____________ C.E.T.

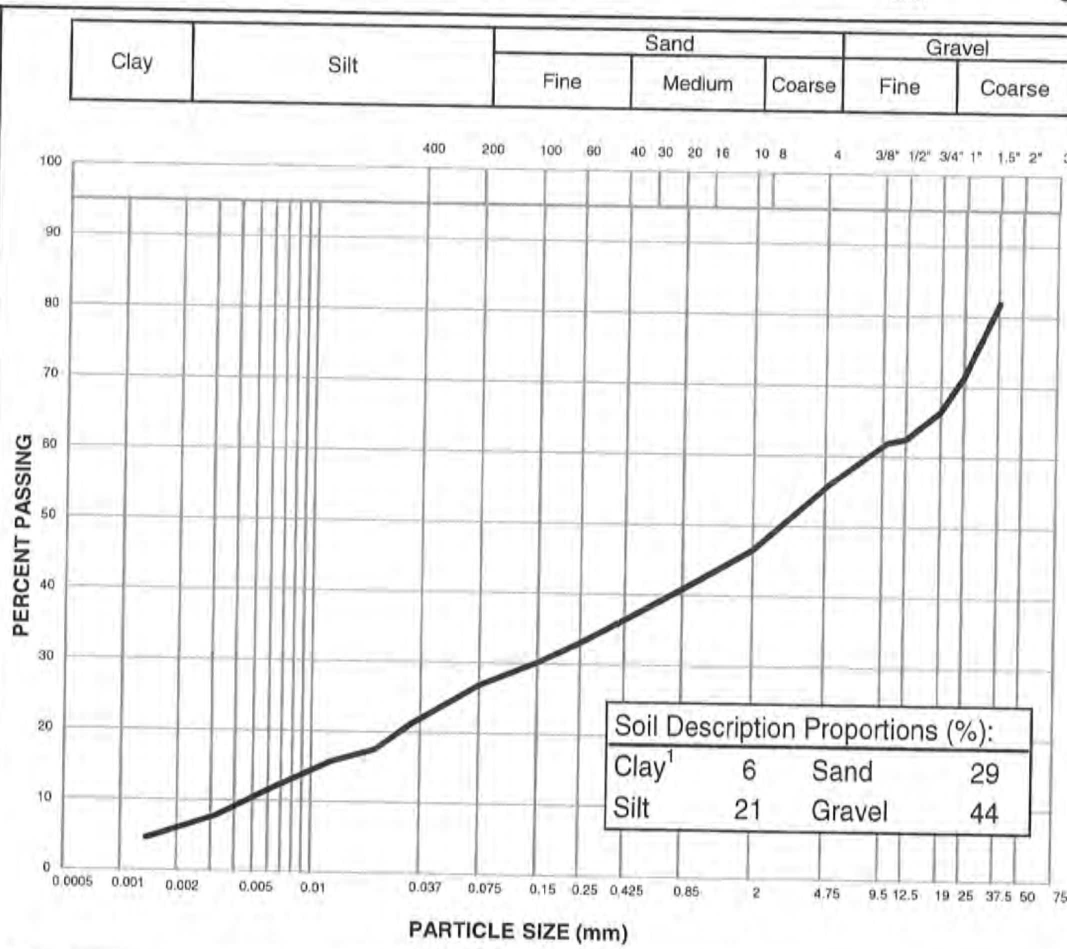
TETRA TECH

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	58568
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	15-SWC-997
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	23.09 - 23.43 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 5, 2015 By: AMT	Date sampled:	February 9, 2015
Soil Description[2]:	GRAVEL - sandy, silty, trace clay	Sampled By:	Client
		USC Classification:	Cu: 1712.3
Moisture Content:	11.7%		Cc: 0.5

Particle Size (mm)	Percent Passing
75	
50	
38	82
25	71
19	66
12.5	63
10	62
5	56
2	47
0.85	41
0.425	36
0.25	33
0.15	30
0.075	26.8
0.0332	21.2
0.0216	17.5
0.0126	15.7
0.0090	13.8
0.0065	12.0
0.0032	7.8
0.0014	4.6



Soil Description Proportions (%):			
Clay[1]	6	Sand	29
Silt	21	Gravel	44

Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: _____________ C.E.T.

TETRA TECH

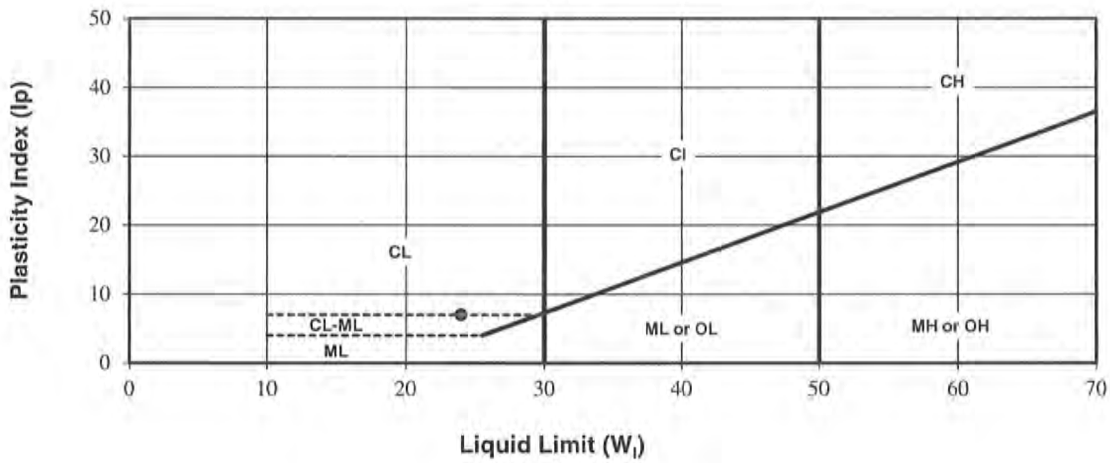
ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	58568
		Borehole Number:	15-SWC-997
Project No:	W14103546-01	Depth:	23.09 - 23.43 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murrary McGregor	Date Sampled:	February 9, 2015
Email:		Date Tested:	March 5, 2015

Sample Description: GRAVEL - sandy, silty, trace clay

Plasticity Chart



Liquid Limit (W_1) :	24	Natural Moisture (%)	35.9
Plastic Limit :	17	Soil Plasticity:	Low
Plasticity Index (Ip) :	7	Mod.USCS Symbol:	CL-ML

Remarks:

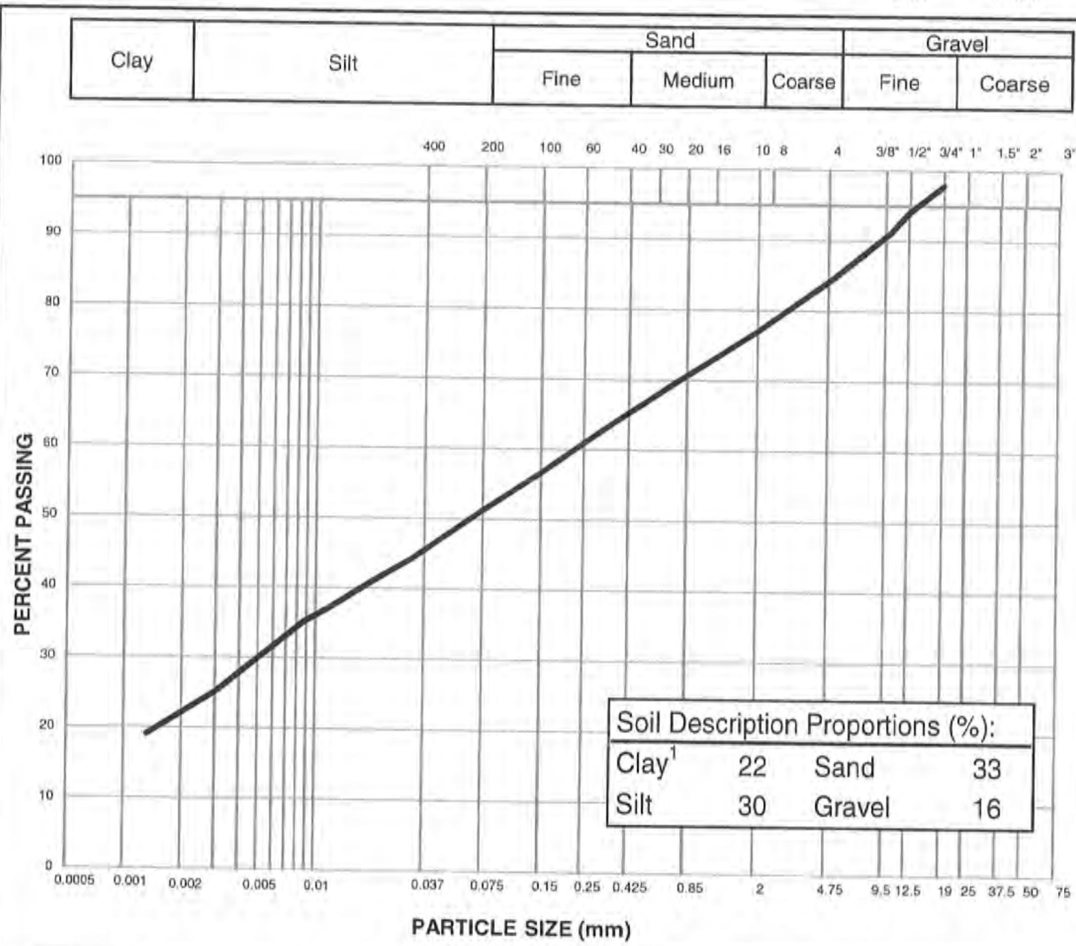
Reviewed By: ______________ C.E.T.

PARTICLE SIZE ANALYSIS REPORT

ASTM D422, C136 & C117

Project:	Minto February 2015 Lab Testing	Sample No.:	58572
Project No.:	W14103546-01	Material Type:	
Site:	Minto Mine, YT	Sample Loc.:	15-SWC-997
Client:	SRK Consulting (Canada) Inc.	Sample Depth:	41.32 - 41.67 m
Client Rep.:	Murray McGregor	Sampling Method:	Grab
Date Tested:	March 5, 2015 By: AMT	Date sampled:	February 9, 2015
Soil Description[2]:	CLAY - sandy, silty, some gravel	Sampled By:	Client
		USC Classification:	Cu: #N/A
Moisture Content:	12.7%		Cc: #N/A

Particle Size (mm)	Percent Passing
75	
50	
38	
25	
19	98
12.5	94
10	91
5	85
2	77
0.85	71
0.425	65
0.25	61
0.15	57
0.075	51.3
0.0315	44.2
0.0202	41.2
0.0120	37.3
0.0086	35.1
#N/A	28.7
0.0030	25.2
0.0013	19.1



Notes: [1] The upper clay size of 2 um, per the Canadian Foundation Engineering Manual

[2] The description is visually based & subject to EBA description protocols

Specification:

Remarks:

Reviewed By: ____________ C.E.T.

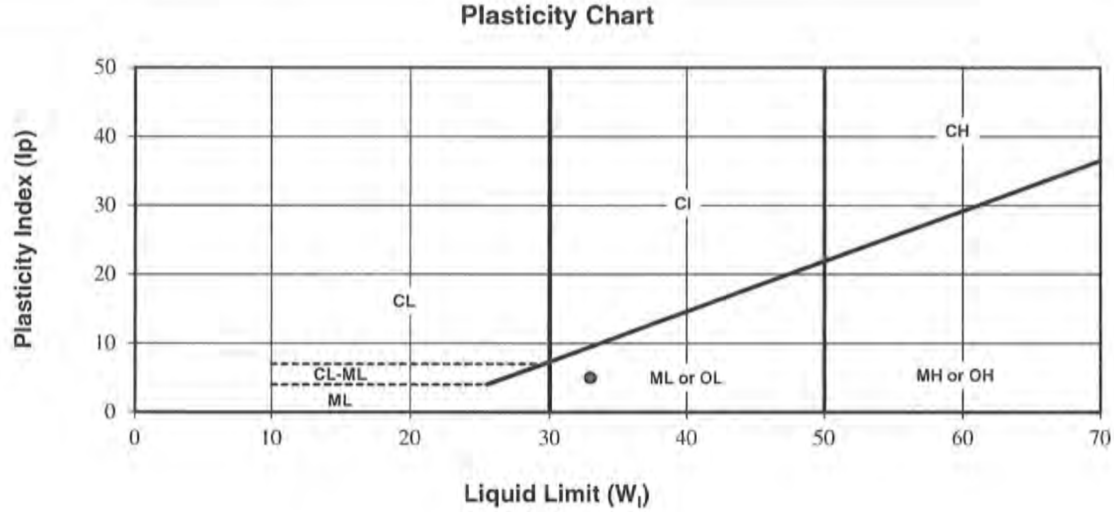
TETRA TECH

ATTERBERG LIMITS TEST REPORT

ASTM D4318

Project:	Minto February 2015 Lab Testing	Sample Number:	58572
		Borehole Number:	15-SWC-997
Project No:	W14103546-01	Depth:	41.32 - 41.67 m
Client:	SRK Consulting (Canada) Inc.	Sampled By:	Client Tested By: AMT
Attention:	Murrary McGregor	Date Sampled:	February 9, 2015
Email:		Date Tested:	March 6, 2015

Sample Description: CLAY - sandy, silty, some gravel



Liquid Limit ($W_{1)}$:	33	Natural Moisture (%)	12.7
Plastic Limit :	28	Soil Plasticity:	Low
Plasticity Index (Ip) :	**5**	Mod.USCS Symbol:	ML

Remarks:

Reviewed By: ________ C.E.T.

TETRA TECH

Appendix C – Minto Closure Cover Design – Cover System Erosion Analysis

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Memo

To:	Project File	**Client:**	Minto Exploration Ltd.
From:	Jordan Graham, EIT, Erik Ketilson, PEng.	**Project No:**	1CM002.49
Reviewed by:	Maritz Rykaart, PEng.	**Date:**	July 26, 2016
Subject:	Minto Closure Cover Design - Cover System Erosion Analysis		

1 Introduction

SRK Consulting (Canada) Inc. (SRK) is currently undertaking the update to the closure plan for the Minto Site. Understanding the erosion process is important such that suitable landform designs can be completed, as erosion can significantly alter an engineered landscape.

The purpose of this memo is twofold: first to update the previous erosion analysis completed as part of the closure landform design and reclamation landform unit work completed by SRK (SRK, 2016); and secondly to present the potential effects of erosion due to sheet and rill water erosion that could occur on the engineered slopes at the Site, and evaluate a range of conditions and parameters to help guide the landform designs at Minto. Sheet and rill water erosion occurs as a result of flows that are not concentrated into a particular flow path.

Erosion that may occur within channel flow and the necessary protection to avoid channel erosion is not addressed in this memo.

All calculated erosion estimates are presented as “soil loss”. Soil loss is a mass or depth of eroded material that leaves the slope entirely. Therefore, the estimates within this memo are not representative of the total volume of material that is displaced by water. Although the calculation does not report material that is detached and deposited along the slope, it is factored into the overall calculation.

2 Soil Loss Estimation Methods

There are several methods available for estimating water erosion including the Universal Soil Loss Equation (USLE) (USDA, 1978), the Revised Universal Soil Loss Equation (RUSLE) Versions 1 (USDA, 1997) and 2 (USDA, 2008), the Revised Universal Soil Loss Equation for Use in Canada (RUSLEFAC) (Wall, 2002), the Water Erosion Prediction Project (WEPP) (Flanagan, 2007), SIBERIA (Willgoose, 2005), and many others. Most of these programs take several factors into account to compute soil loss such as climate, topography, soil type, vegetation, and land management practices. The key difference between these methods is that some are based on empirical data while others are based on a mathematical approach using soil physics. The USLE and its variations are largely based on empirical data, while WEPP and SIBERIA are based on soil physics. RUSLE Version 2 is based on empirical data, but uses soil physics to fill in gaps in empirical data.

The USLE was developed in 1960 and then revised in 1978 (RUSLE) by the United States Department of Agriculture. The empirical relationships in the RUSLE were modified by the Provincial and Federal Governments in 2001 for use in Canada (RUSLEFAC) (Wall et al., 2002). The RUSLEFAC uses metric units and input parameters that apply to Canadian conditions.

The soil loss analysis described within this Memo uses only the RUSLEFAC method. The RUSLEFAC has an advantage over other current methods in that it can be calculated manually and the effects related to the variability of each of the input parameter can be thoroughly evaluated.

3 RUSLEFAC Scope and Limitations

The RUSLEFAC (Wall et al., 2002) is a tool for calculating sheet flow erosion and rill erosion, and as stated in Section 2, is based on empirical data. The experimental soil plots used to develop the equations were subjected to conditions that generally reflected average annual climatic conditions. Therefore, the intent of the RUSLEFAC is to produce a numerical representation of an average annual quantity of soil loss in the units of tonnes per hectare per year, which can be converted to depth per year given an understanding of the soil’s in-situ density. The equation is a useful tool for long term predictions, and can also be used for short term losses; however, due to the nature of the experimental data that was collected to develop the equations, short term estimates are likely associated with a greater degree of error.

The RUSLEFAC has the following limitations (Wall et al., 2002):

- It does not accurately estimate soil loss from a single rainfall event. However, the erosivity of a single storm can be estimated using the method described in the RUSLE;
- It does not account for erosional losses once gullies or streams form;
- Although there is some account for erosional losses due to snow melt, the equation does not account for this loss with great accuracy; and
- Freeze/thaw can cause ice lenses in soil that will affect the rate of soil loss: the RUSLEFAC does not take this into account.

Ice lensing is typically a greater issue in areas where repeated freeze/thaw cycles occur during one winter season. At the site, however, the surface material is more likely to freeze in the fall and stay frozen throughout the winter and into the spring without repetitive freeze/thaw action. Therefore, the impact of freeze-thaw on the results of the analysis for the Minto site is not considered to be a major influencing factor on erosion of the cover.

4 Design Criteria

Table 4-1 presents the soil erosion classes included in the RUSLEFAC.

Table 4-1: Soil Erosion Classes

Soil Erosion Class	Potential Soil Loss (T/ha/year)
1. Very Low (i.e. tolerable)	< 6
2. Low	6-11
3. Moderate	11-22
4. High	22-33
5. Severe	> 33

For the Minto site, in an effort to minimize erosion of cover material, there is a preference to achieve a Class 1 soil erosion class. In cases where the native Minto soils may not naturally meet a Class 1 soil erosion classification, additional mitigation measures, or support practices may be necessary to achieve very low rates of erosion. The RUSLEFAC considers Class 1 soils to have:

> "Slight to no erosion potential. Minimal erosion problems should occur if good soil conservation management methods are used... A tolerable soil loss (<6 T/ha/year) is the maximum annual amount of soil which can be removed before the long term natural soil productivity of a hillslope is adversely affected." (Wall et al., 2002).

5 RUSLEFAC Equation

The RUSLEFAC equation is calculated manually by first determining several inputs. The RUSLEFAC equation is:

$$A = RKLSCP$$

Where,

A is the potential long term average annual soil loss in tonnes per hectare. *A* can be converted to depth per year if the density of the soil is known.

R is the rainfall factor, which is expressed in energy multiplied by depth over area times duration (MJmm/hah), is calculated using the equation:

$$R = EI$$

Where *E* is the volume of rainfall and runoff (mm/ha) and *I* is the prolonged peak rate of detachment that occurs with runoff (MJ/h).

- R value contours (isoerodent maps) have been developed by the Government of Canada and are included in the RUSLEFAC document (Wall et al., 2002). To determine the R value in a particular area, interpolation between contours is often required.

- R can be calculated for a single storm event using the R equation if the storm distribution is known or can be estimated.

K is the soil erodibility factor, which is expressed in terms of area multiplied by duration over energy times depth (hah/MJmm).

- *K* is dependent on the sand content, fine sand content, silt content, organic matter content, soil structure, and permeability of the soil.
- *K* is determined by applying the appropriate parameters to the soil erodibility nomograph included in the RUSLEFAC.

L is the length of slope factor (dimensionless).

S is the slope steepness factor (dimensionless).

- *L and S* are typically presented as a single value.
- The *LS* factor represents a ratio of soil loss in comparison to a “standard plot”, which is an experimental plot that has a steepness of 9% and a slope length of 22.13 m. Charts based on experimental data are included in the RUSLEFAC document (Wall et al., 2002), which is used to determine the *LS* factor.
- The *LS* factors presented in the RUSLEFAC are representative of straight slopes, but can be manipulated to represent complex slopes (i.e. convex, concave, slopes with benches).

C is the cover factor (dimensionless).

- *C* is *dependent* on the vegetative cover and the land use.
- This factor is based on tables available in the RUSLEFAC document (Wall et al., 2002).

P is the support practice factor (dimensionless).

- The support practice factor accounts for the effects of practices that may reduce the volume or rate of runoff water by altering the flow pattern, surface grade, or direction of surface runoff.

6 RUSLEFAC Inputs

To determine the impact and sensitivity of the input variables on soil loss, a range of values were used for each variable. The ranges of input values are discussed in the following subsections. The results of the analyses using the discussed ranges of input values are included in Section 7.

6.1 Erosivity/Rainfall Factor (R)

Annual erosivity represents the average precipitation energy that causes soil loss over the course of an average year. The annual erositivity value can be used to determine the cumulative soil loss over a long period of time.

Annual R values are not shown on the Canadian Isoerodent Maps in the Yukon Territory near the Site. As discussed in Section 5, erosivity is greatly dependent on rainfall. Therefore, to determine the erosivity at the site, SRK compared total annual precipitation as rainfall to erosivity in locations with known erosivities, then applied the trends to the site (annual precipitation as rainfall for the site was taken from Environment Canada's Pelly Crossing Station). Based on the application of the trends, the erosivity at the site likely falls within the range of 200 to 240 MJmm/hah. For conservatism, SRK applied a 25% contingency to the upper end of the range. The conservatively estimated R value for the site is therefore 300 MJmm/hah.

Soil loss estimates for short term periods (i.e. single storm events) were not included in this analysis.

6.2 Soil Erodibility Factor (K)

Figure 1 illustrates the particle size distribution data plotted in accordance with the USDA Soil Textural classification, and the general site area from which that sample was obtained. Figure 1 also illustrates the average of all samples (on which the majority of this analysis is completed), and the upper (maximum) and lower (minimum) bounds, discussed in further detail in Section 7.4. The material available for cover is generally classified as a sandy loam. Material properties from 70 soil samples were averaged and evaluated using the soil erodibility nomograph (Wall et al., 2002); the resulting K value was 0.027. Approximate minimum and maximum K values were then estimated using the soil erodibility nomograph, which were 0.011 and 0.051, respectively.

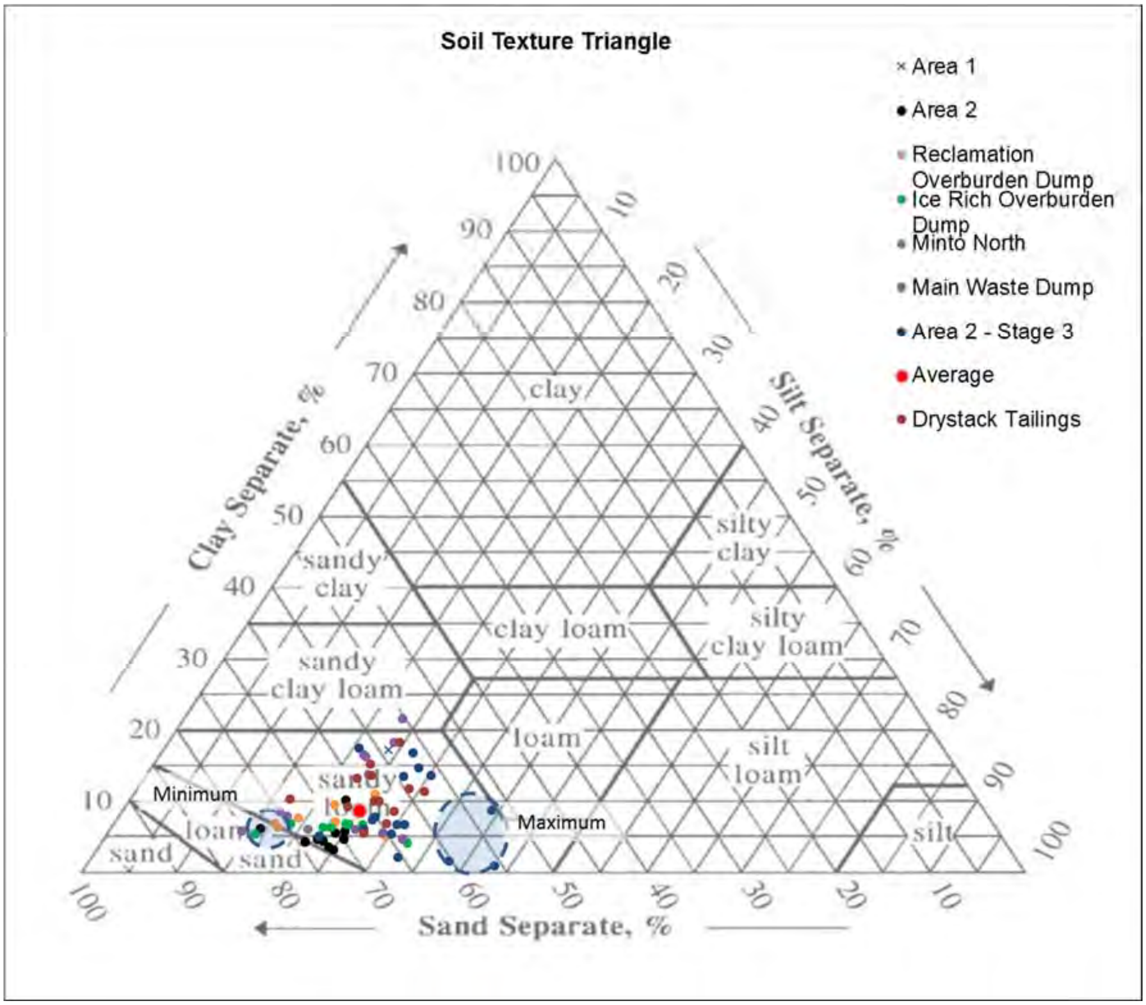

Figure 1: Soil Texture Triangle

6.3 Length and Slope Steepness Factors (L&S)

Several different straight and complex slopes were assessed. Straight slopes of 6H:1V, 5H:1V, 4H:1V, 3.5H:1V, 3H:1V, 2.5H:1V, and 2H:1V were each assessed for lengths of 10 m up to 200 m.

A variety of complex slopes were assessed that each had an average slope of 4H:1V and a length of 100 m. The complex slopes were assessed for the same length and slope to show the comparative difference between each type of slope. The complex slopes included four concave slopes (consisting of two to four straight segments), a straight slope with one 10 meter bench, and a straight slope with two 10 meter benches (the straight portions consisted of 4H:1V slopes, therefore the overall slope was substantially flatter than 4H:1V). The types of slopes that were assessed are illustrated in Figure 2. The figure indicates the horizontal to vertical slopes, but it is not drawn to scale.

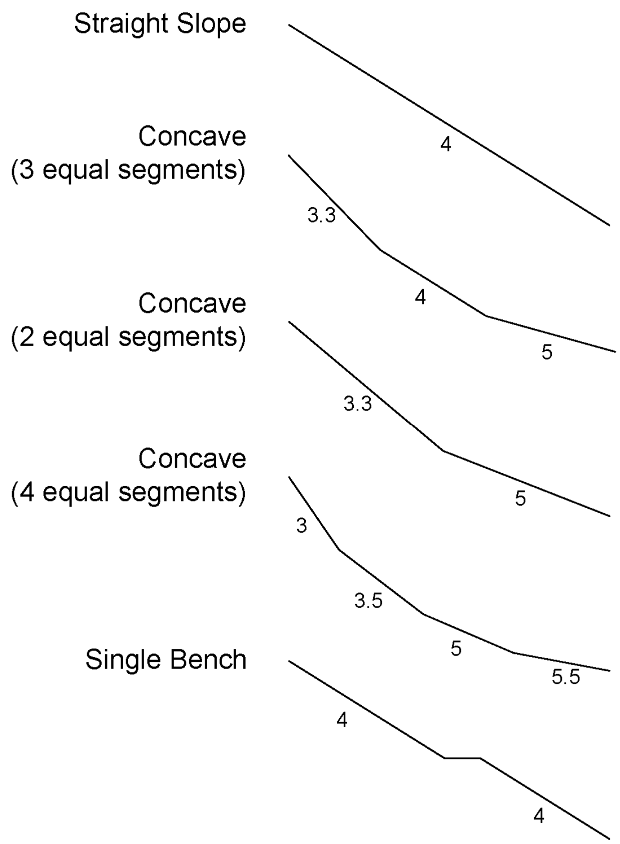

Figure 2: Types of Slopes Assessed

6.4 Cover Factor (C)

The *C* factor was determined using Table C-5 in the RUSLEFAC. Values decrease with lesser cover (yielding lesser soil loss). The value for bare, undisturbed soil with no vegetative canopy (canopy is considered having plants/weeds/shrubs of 0.5 m height or greater) or surface cover is 0.45. The value for 40% small, short-rooted plant coverage with no canopy is 0.15, and the value for 40% small, short-rooted plant coverage with a taller plant canopy is 0.13. Increasing small, short-rooted plant coverage to 80% with canopy decreases the cover factor to 0.04.

6.5 Support Practice Factor (P)

The base case P factor was to have no impact the on the soil loss equation and was made equal to one. The support practice factor is proportional to soil loss (i.e. a support practice factor of zero will yield zero soil loss).

Short term support practices could be incorporated into the design to support the process of establishing vegetation on the slopes. The support practices are likely to include slope texturing, sediment fencing (or other flow velocity reduction measures), and/or the use of rolled erosion control products. The respective support practice factors are 0.9, 0.6, and 0.1 respectively (Alberta, 2011). As stated, although not included as base case conditions, the effect of support practices was included as a sensitivity to demonstrate the impact in reducing soil loss.

7 Results and Discussion

The figures within this section show soil loss in units of tonnes per hectare per year (T/ha/year) and in millimeters per year (mm/year). The depth per year values were determined using an average dry density of 1.6 T/m³. The depth represents the average depth of soil loss over the entire erodible surface area. The guideline values for the Class 1 soil erosion class of 6 T/ha/year corresponds to a depth of 0.35 mm/year. The guideline values are not shown on Figures 5, 6, and 7, as these figures are intended to show the relative difference of how certain parameters affect erosion, and were not necessarily intended to show the design slopes that will be selected at the site.

7.1 Straight Slopes

Figure 3 illustrates the expected straight slope soil loss with the average available material if no vegetative cover is established. None of the scenarios meet the target of 6 T/ha/year.

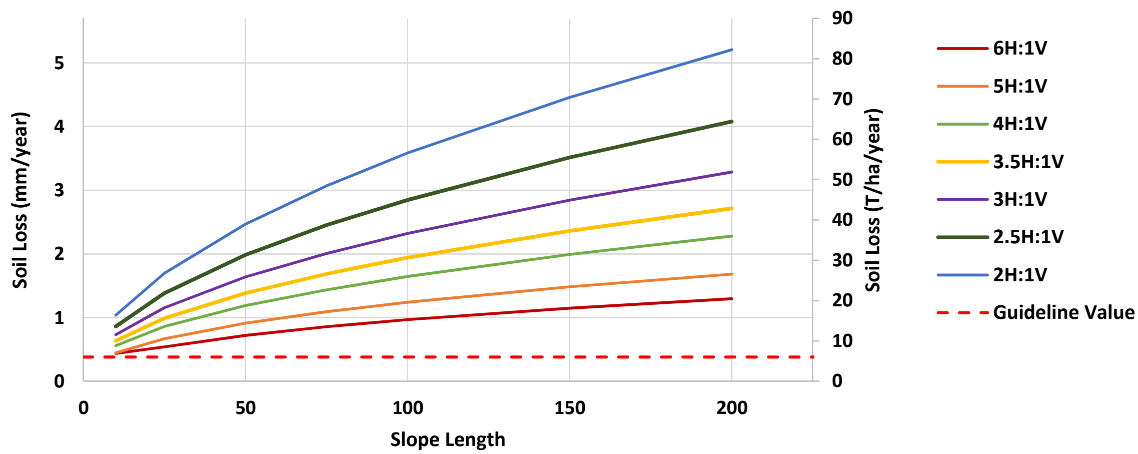

Figure 3: Straight Slopes using Average Material with no Vegetative Cover

7.2 Effects of Vegetation

Figure 4 illustrates the expected straight slope soil loss with 80% small, short-rooted plant coverage and no vegetative canopy. Comparing Figure 3 and Figure 4 shows that established vegetation significantly reduces soil loss due to water erosion. Most of the assessed slope conditions meet the target of 6 T/ha/year.

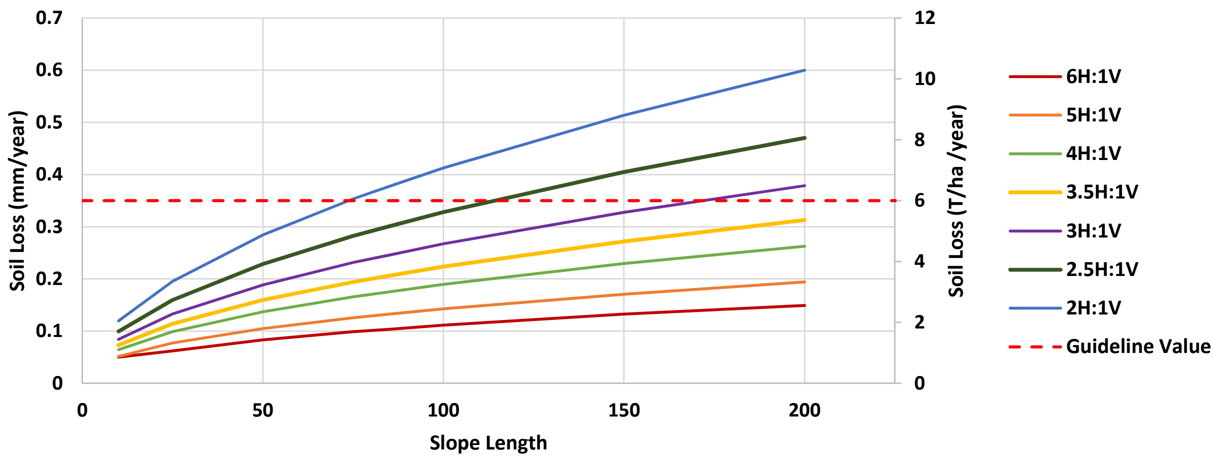

Figure 4: Straight Slopes using Average Material with 80% Small, Short-rooted Plant Coverage and No Vegetative Canopy

Figure 5 shows the effects that increased vegetation coverage have on a particular slope. The figure shows that achieving at least some vegetation coverage (20%) reduces soil loss due to erosion by a significant margin.

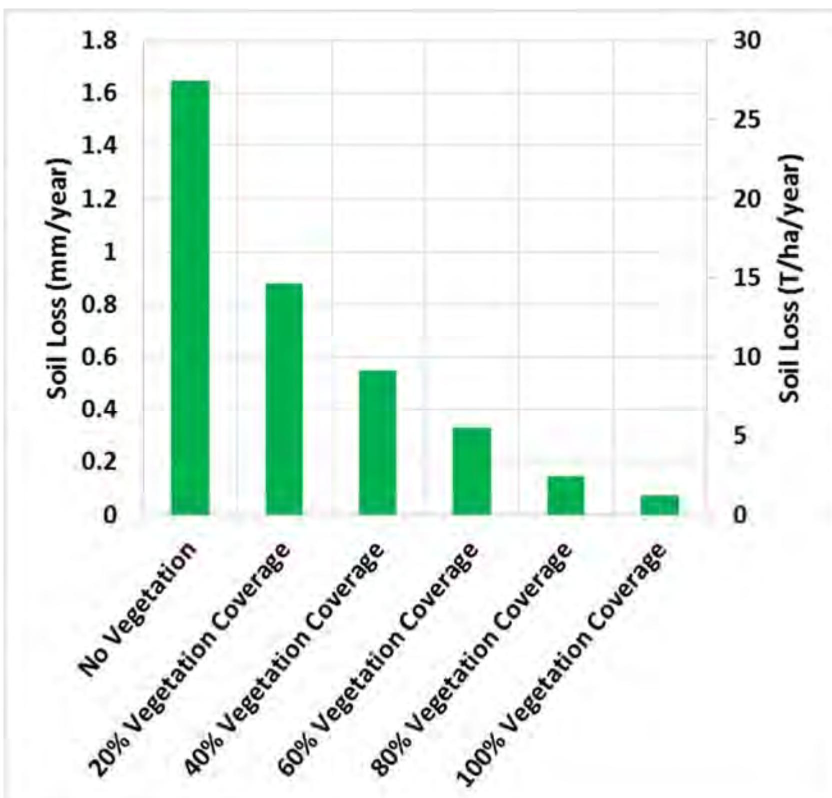

Figure 5: The Effects of Vegetation Coverage on a 4H:1V, 100 m Slope with Average Material

7.3 Effects of Complex Slopes

The soil losses for 100 m long complex slopes at 4H:1V with no vegetative cover and average site material are shown in Figure 6. The figure indicates that each of the complex slopes yields less soil loss than an equivalent straight slope. Complex slopes were somewhat effective at reducing soil loss in this analysis: soil loss was approximately 9% less on concave slopes than on straight slopes. Although only 100 m, 4H:1V slopes are presented, SRK has determined via the RUSLEFAC, the reduction in soil loss on complex slopes is similar for other slopes and slope lengths in the same order of magnitude (i.e. 5H:1V slopes, 50 to 125 m slope lengths). The soil loss reductions are expected to be less similar to those presented if the slope length or steepness is increased substantially.

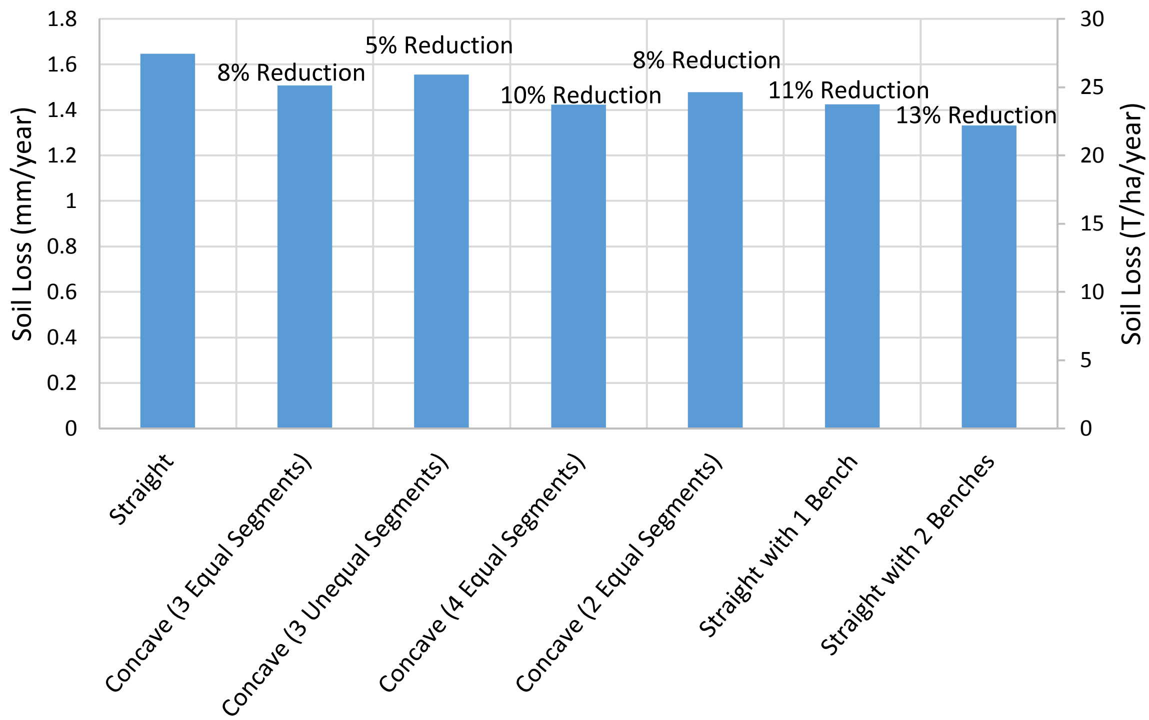

Figure 6: Complex Slope Comparison (100 m Long at 4H:1V and No Vegetative Cover)

7.4 Effects of Soil Type

The effects of soil type are presented in Figure 7. Each of the soil loss estimates are based on 100 m long 4H:1V straight slopes, and no vegetative cover. The figure indicates the range in erosion susceptible material available on site. It is important that material susceptibility to erosion be considered in design stage of the cover. By choosing material that is more susceptible than the average material available on site, erosion estimates can increase by as much as 100%. More erosion susceptible material contains a greater percentage of silt and fine sand, while less erodible material contains less silt and fine sand. The classification of these soils is described in Section 6.2.

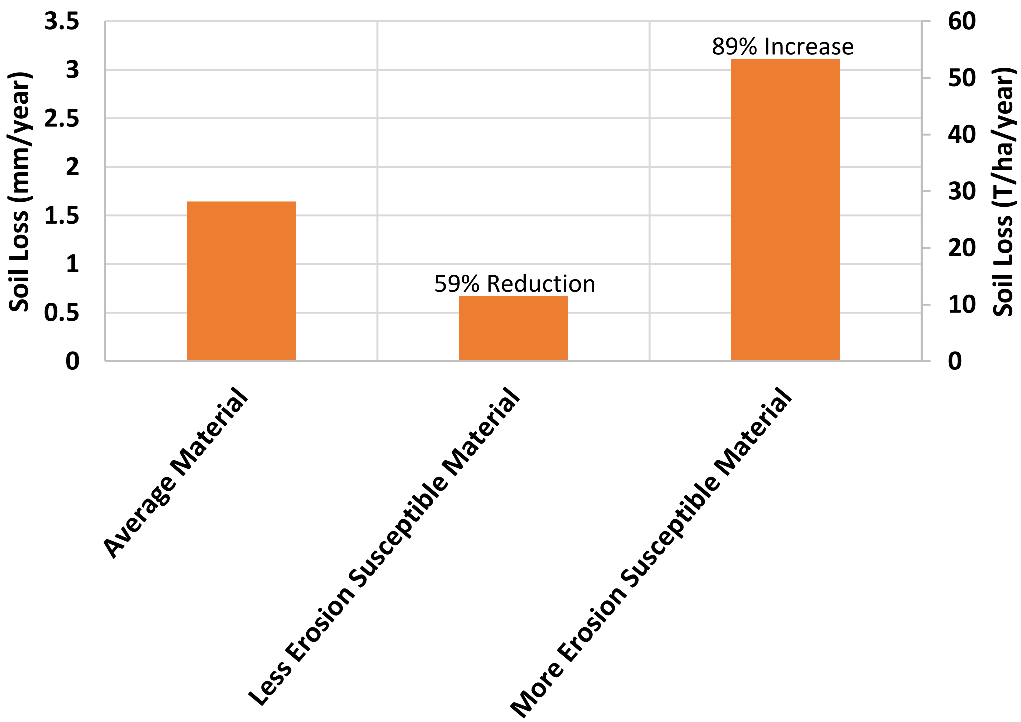

Figure 7: Soil Type Comparison (Based on 100 m Long 4H:1V Straight Slopes)

7.5 Effects of Support Practice Factor

The effects of the support practice factor were evaluated on non-vegetated, 100 m long, 4H:1V slope, covered with average material available on site. The results are presented in Figure 8. The figure shows that through the use of support practices, also commonly referred to as the incorporation of microtopography, the estimates of erosion can be decreased to the target of 6 T/ha/year even without the establishment of vegetation. The use of soil texturing alone will not reduce the rate of erosion to the target; rolled erosion control products would be required to meet the target without vegetation. Sediment fencing is grouped together with wattles as velocity reducers, as their effectiveness in reducing erosion is similar.

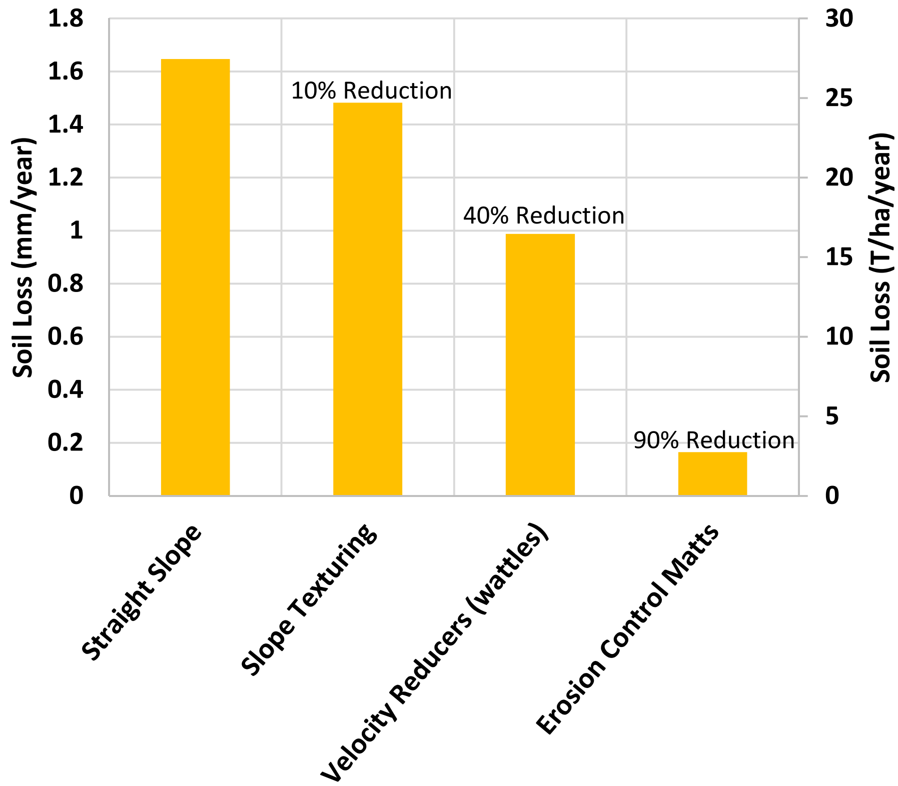

Figure 8: Support Practice Comparison (No Vegetation)

8 Total Soil Loss

Soil loss over the course of the design life was calculated to determine whether the average depth of soil loss would reduce the initial cover thickness to below the required cover thickness. Annual soil loss due to water erosion was multiplied by 100 years to determine design life soil loss, which is presented for several straight slope scenarios in Table 8-1. Average annual soil loss (in T/ha/year) is also presented in the table.

Table 8-1: Calculated Water Erosion Design Life Soil Loss

Slope Condition		**Design Life Soil Loss (mm) per Slope Length**							
		50 m		**85 m**		**100 m**		**150 m**	
		Annual (T/ha/yr)	100 yrs (cm)	Annual (T/ha/yr)	100 yrs (cm)	Annual (T/ha/yr)	100 yrs (cm)	Annual (T/ha/yr)	100 yrs (cm)
Non-Vegetated	**2.5H:1V**	31.8	19.9	41.8	26.1	45.6	28.5	56.2	35.1
	3H:1V	26.2	16.4	34.1	21.3	37.1	23.2	45.5	28.4
	3.5H:1V	22.1	13.8	28.6	17.9	31.0	19.4	37.8	23.6
	4H:1V	19.0	11.9	24.3	15.2	26.4	16.5	31.9	19.9
	5H:1V	14.6	9.1	18.4	11.5	19.8	12.4	23.7	14.8
Vegetated (80% Short-Rooted Plant Coverage)	**2.5H:1V**	3.7	2.3	4.8	3.0	2.3	3.3	6.5	4.1
	3H:1V	3.0	1.9	3.9	2.5	4.3	2.7	5.2	3.3
	3.5H:1V	2.6	1.6	3.3	2.1	3.6	2.2	4.4	2.7
	4H:1V	2.2	1.4	2.8	1.8	3.0	1.89	3.7	2.3
	5H:1V	1.7	1.1	2.1	1.3	2.3	1.4	2.7	1.7

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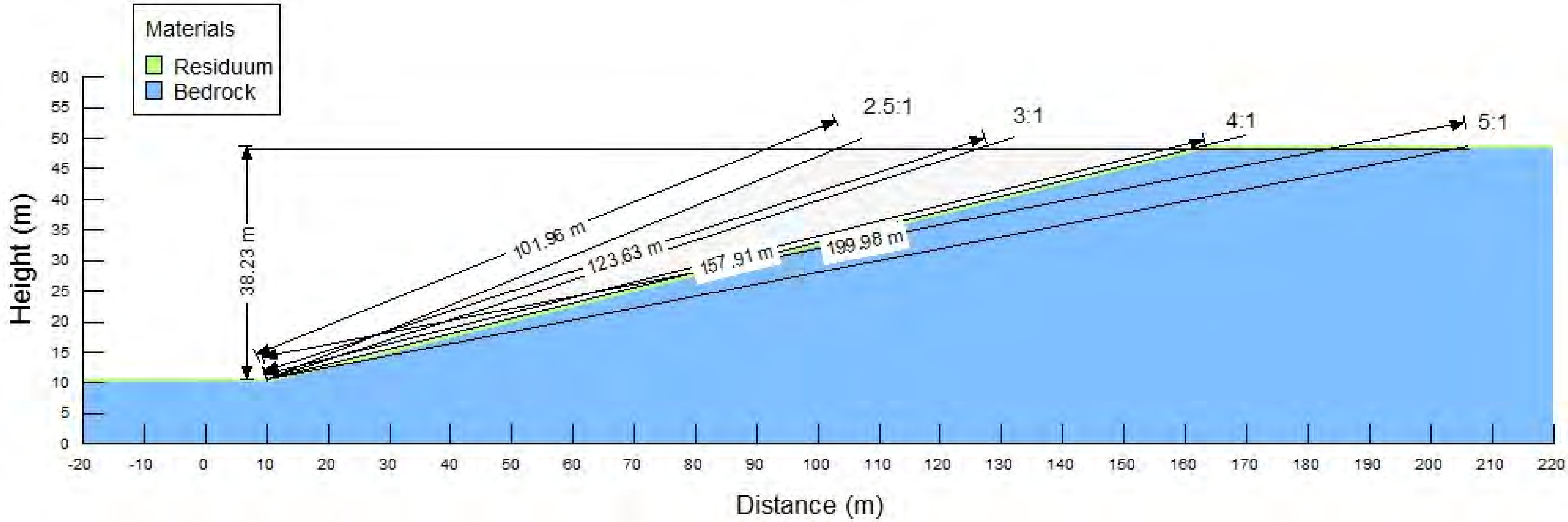
Appendix D – Minto Closure Cover Design – Stability Assessment



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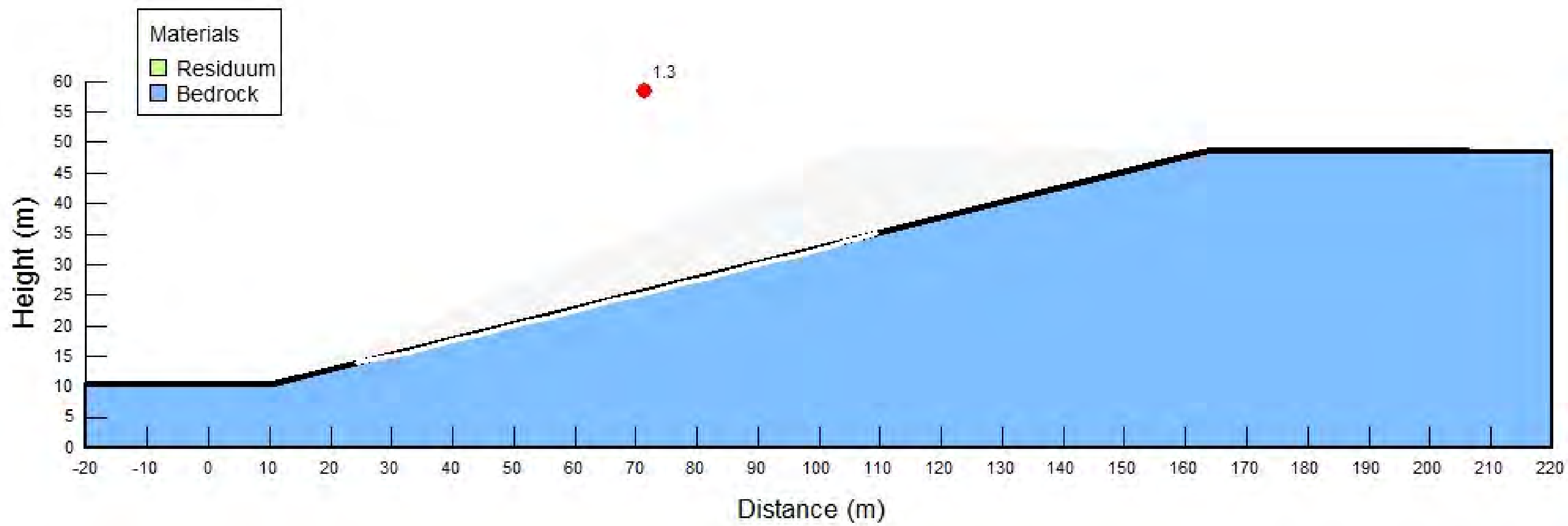

Results

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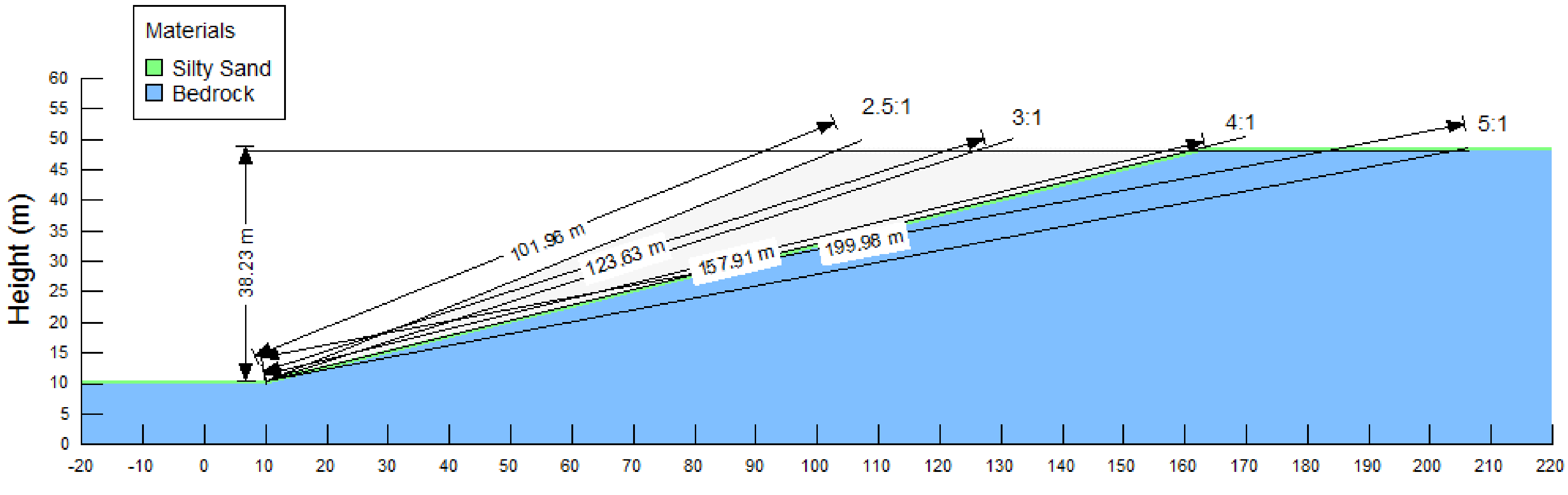

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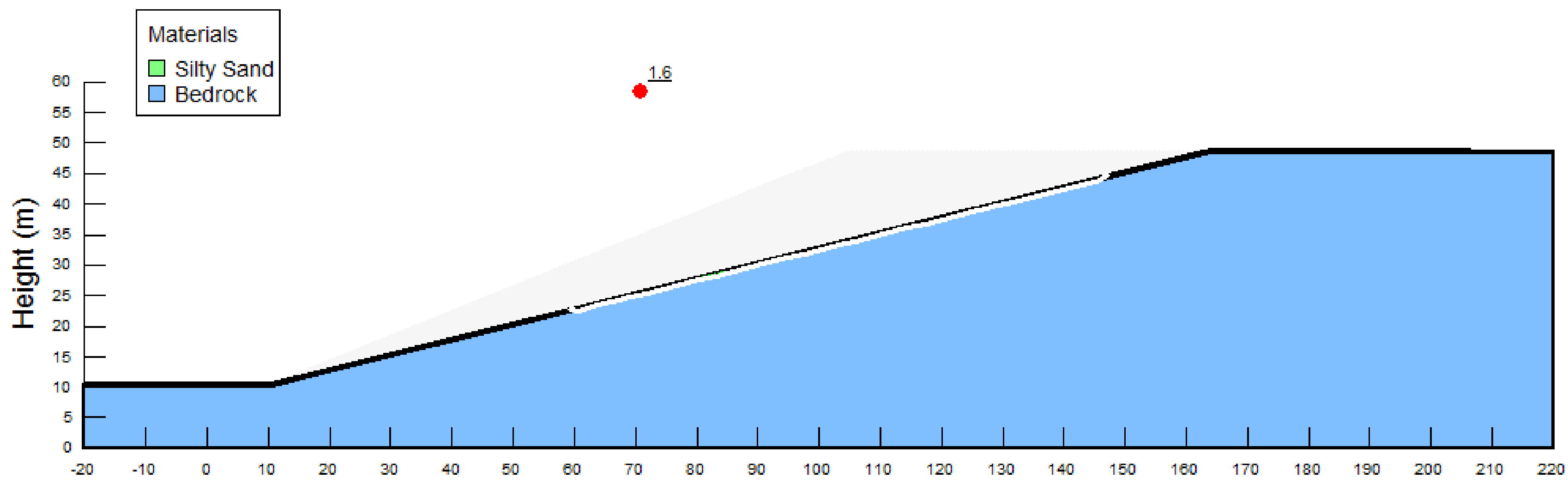

Results

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capstone MINTO MINE
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Stability Assessment

Scenario 2

Job No: 1CM002.049

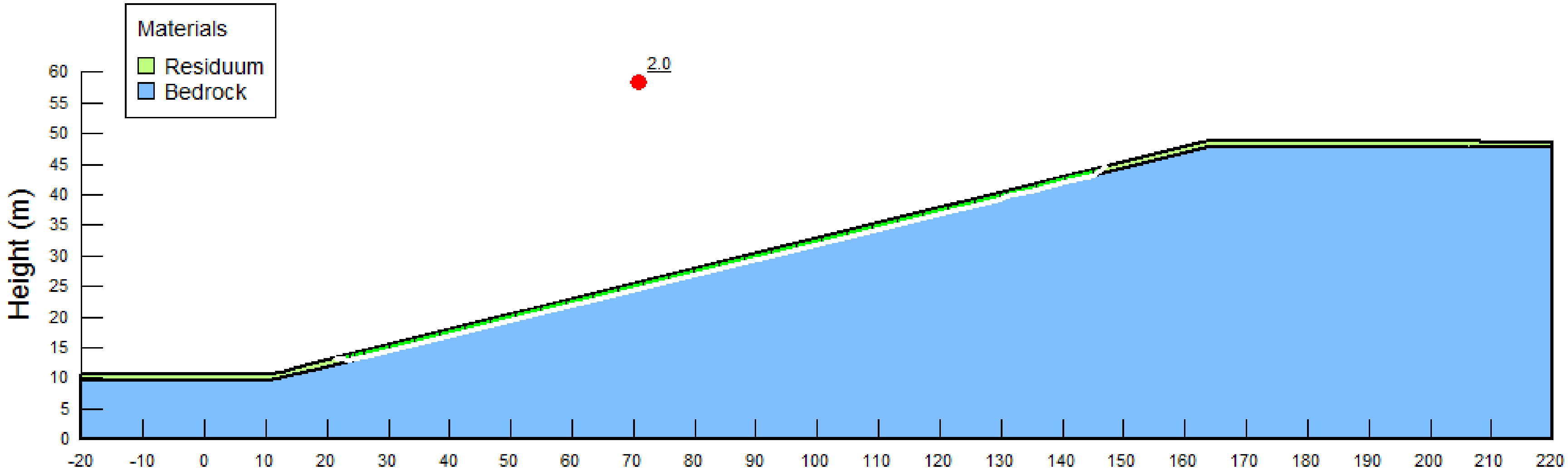
Filename: StabilityAnalysis-Figures-1CM002-049_REV0-EK.pptx

Minto Closure Cover Design

Date: July 2016

Approved: EK

Figure: 2



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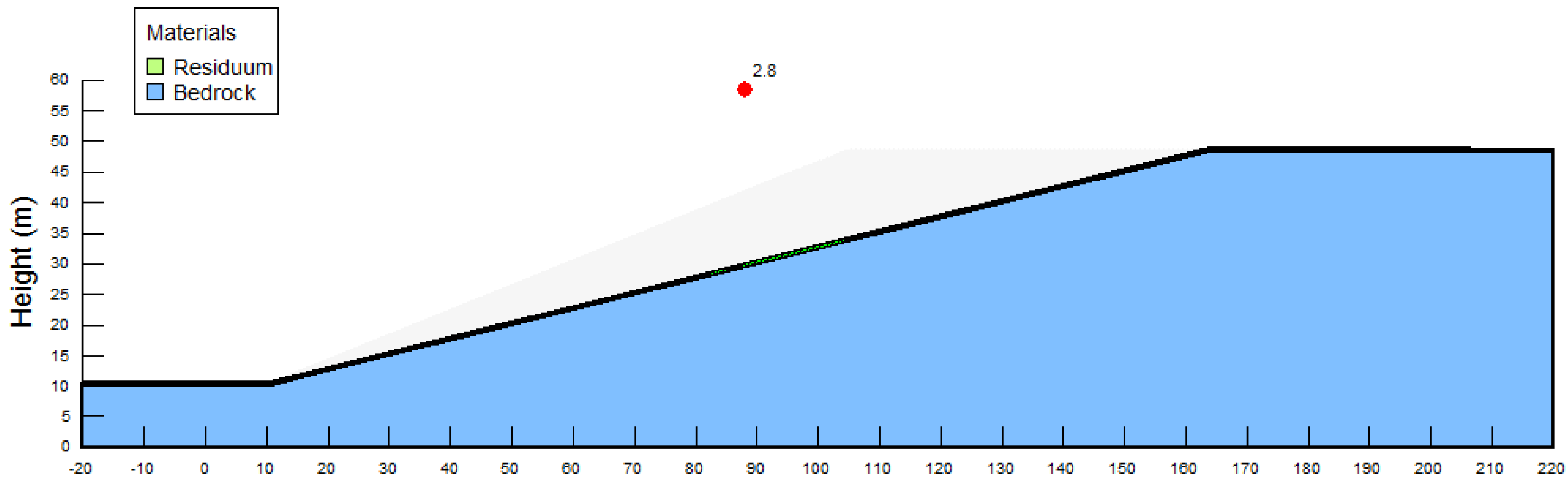

Scenario 1b

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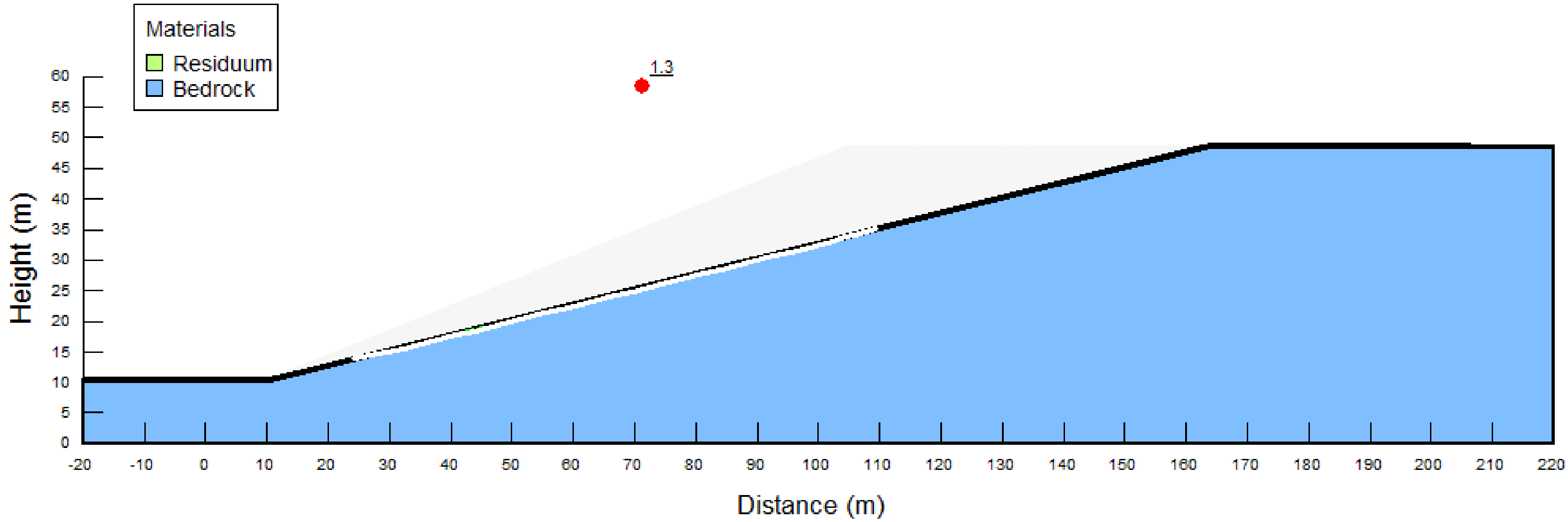
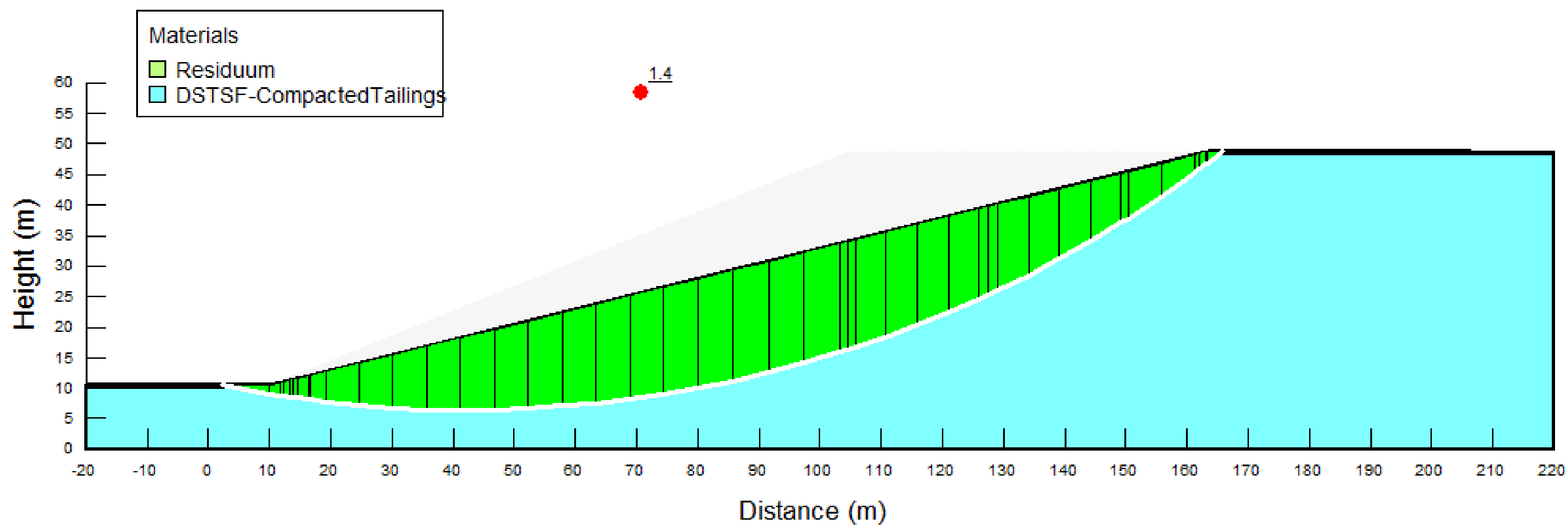


Scenario 1c



Scenario 1d

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Stability Assessment

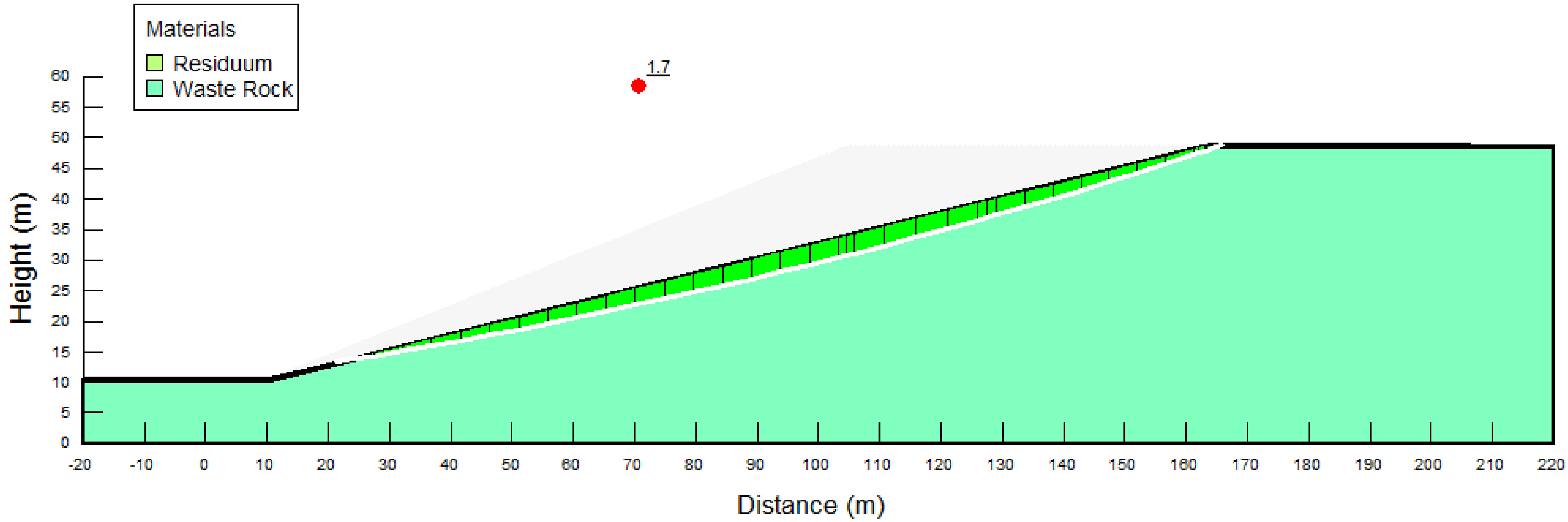
Scenario 1 Sensitivity (con't)

Job No: 1CM002.049

Filename: StabilityAnalysis-Figures-1CM002-049_REV0-EK.pptx

Minto Closure Cover Design

Date:	Approved:	Figure:
July 2016	EK	4



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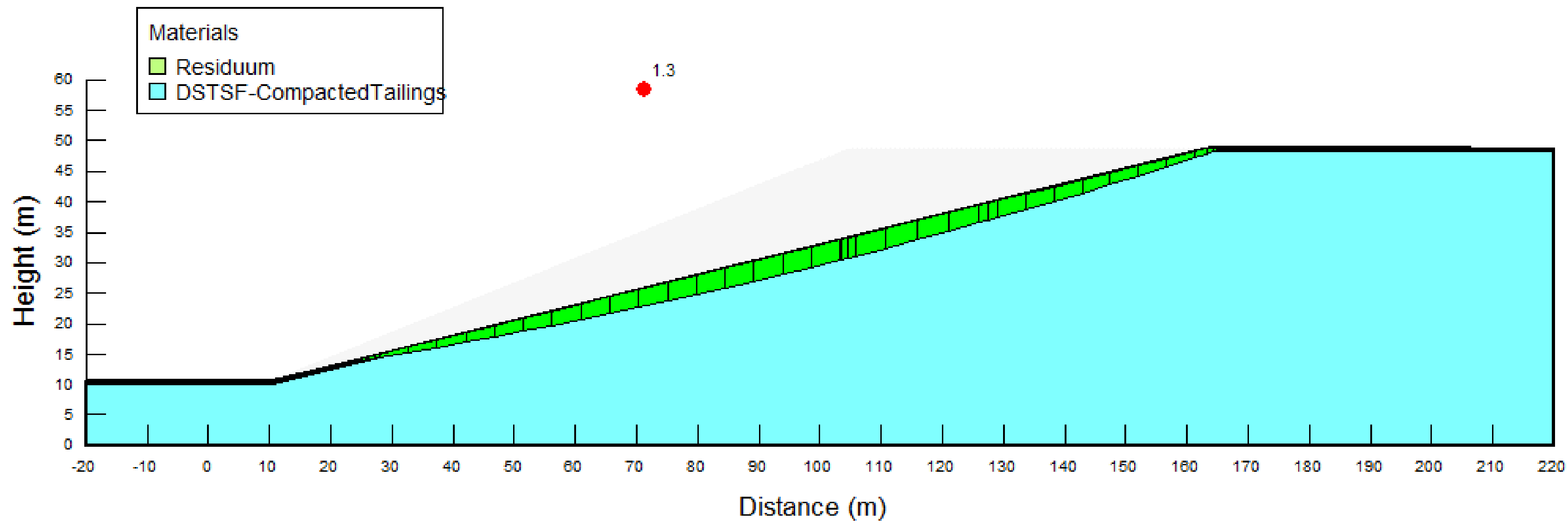

Scenario 1f

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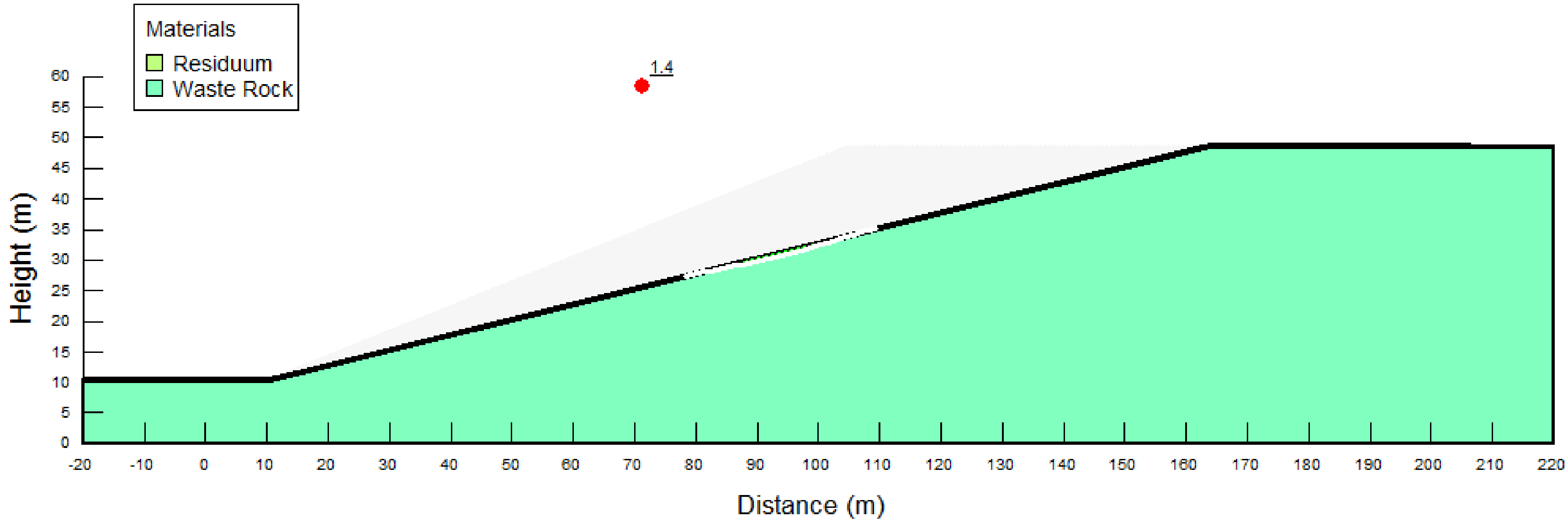

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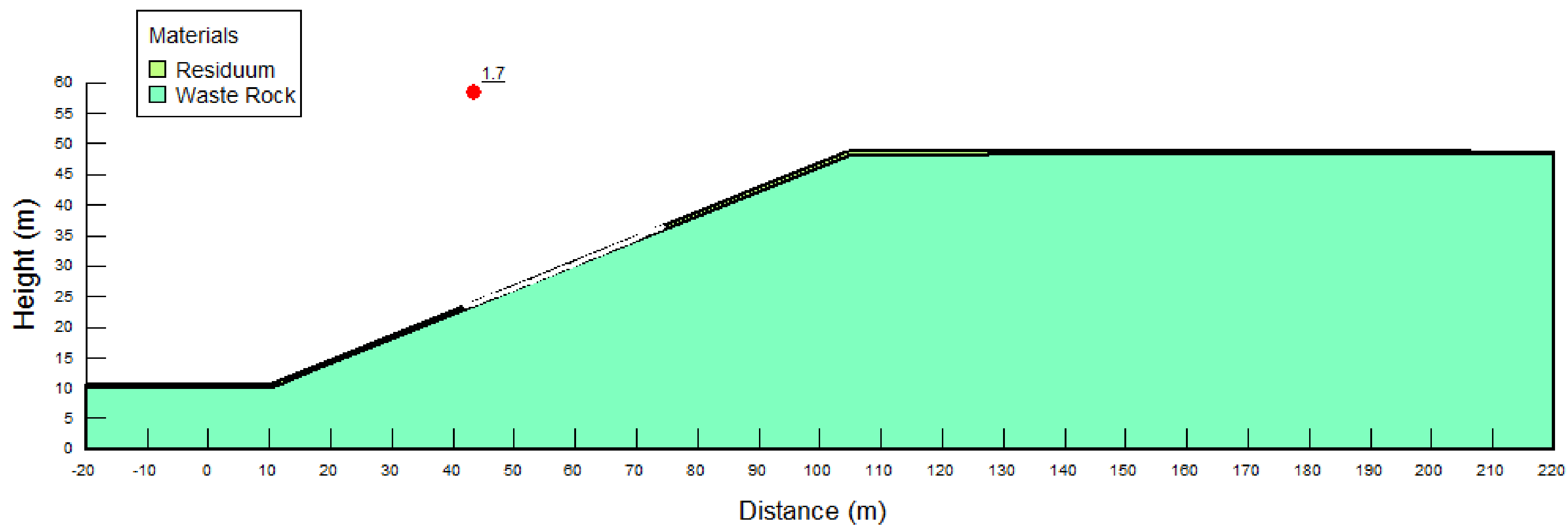

Scenario 1f

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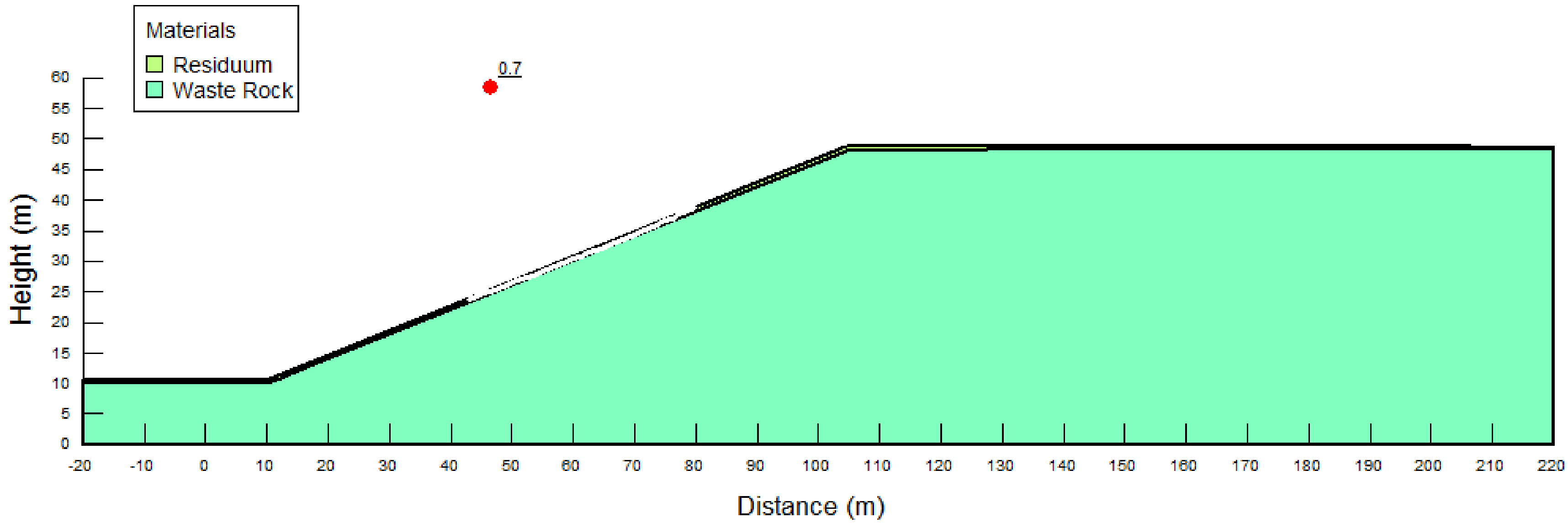

Scenario 1i

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capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.

Stability Assessment

Scenario 1 Sensitivity (con't)

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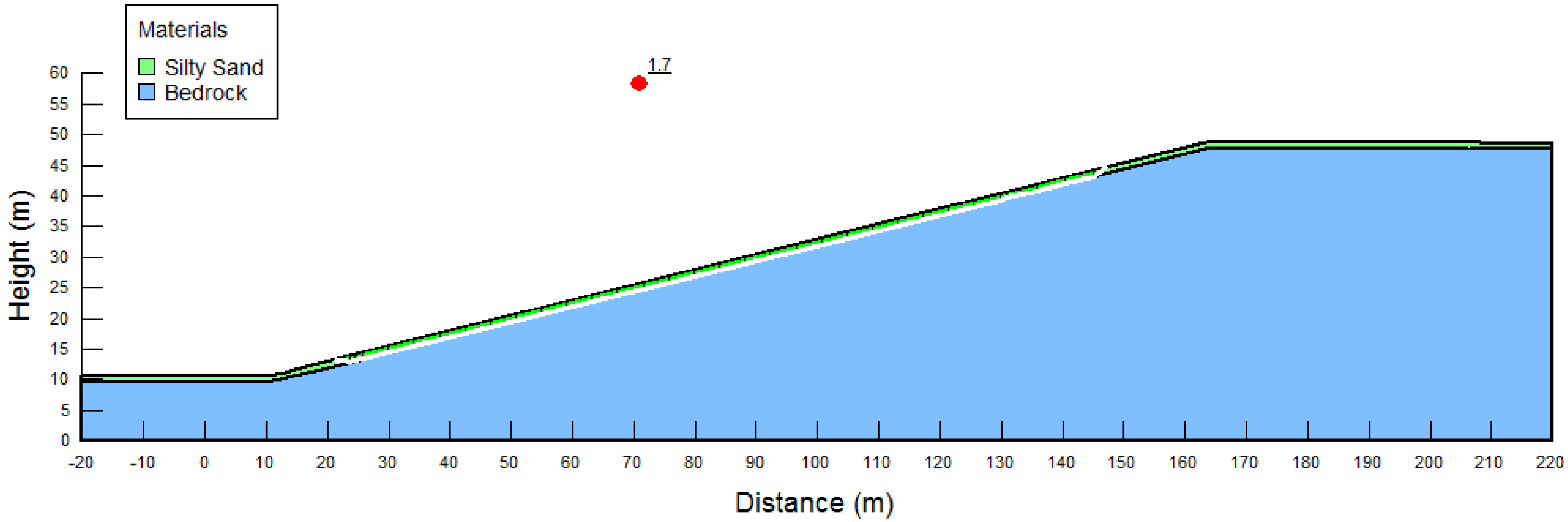
Minto Closure Cover Design

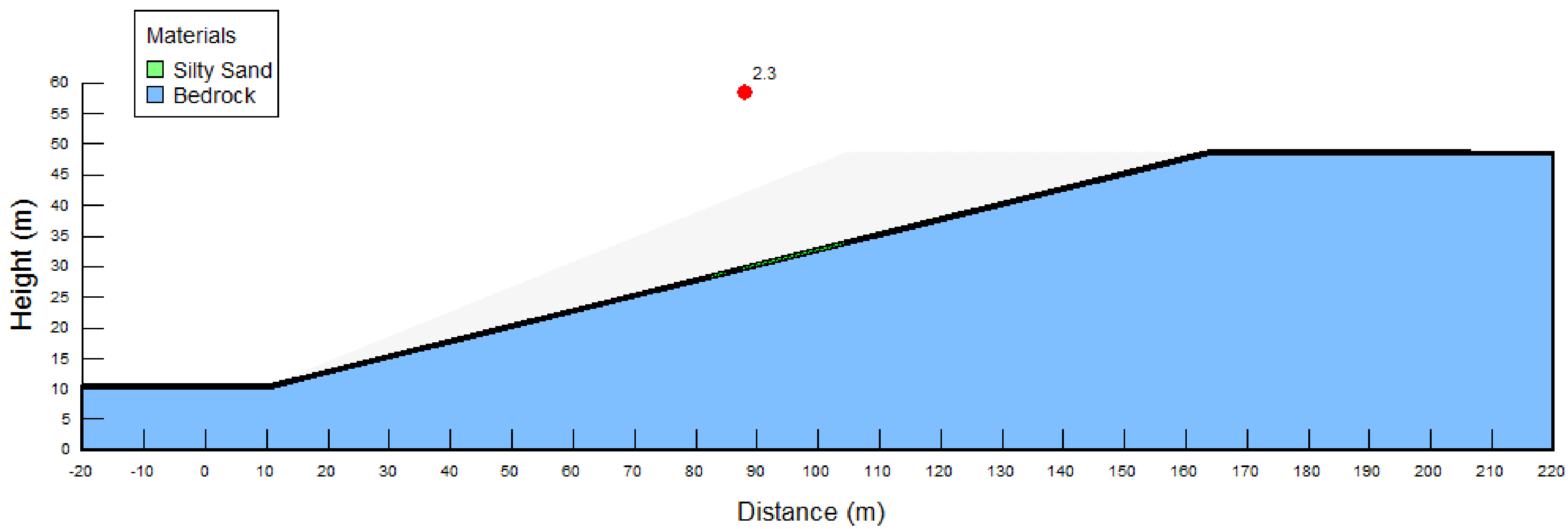
Date: July 2016

Approved: EK

Figure: 7



Scenario 2a



Scenario 2b

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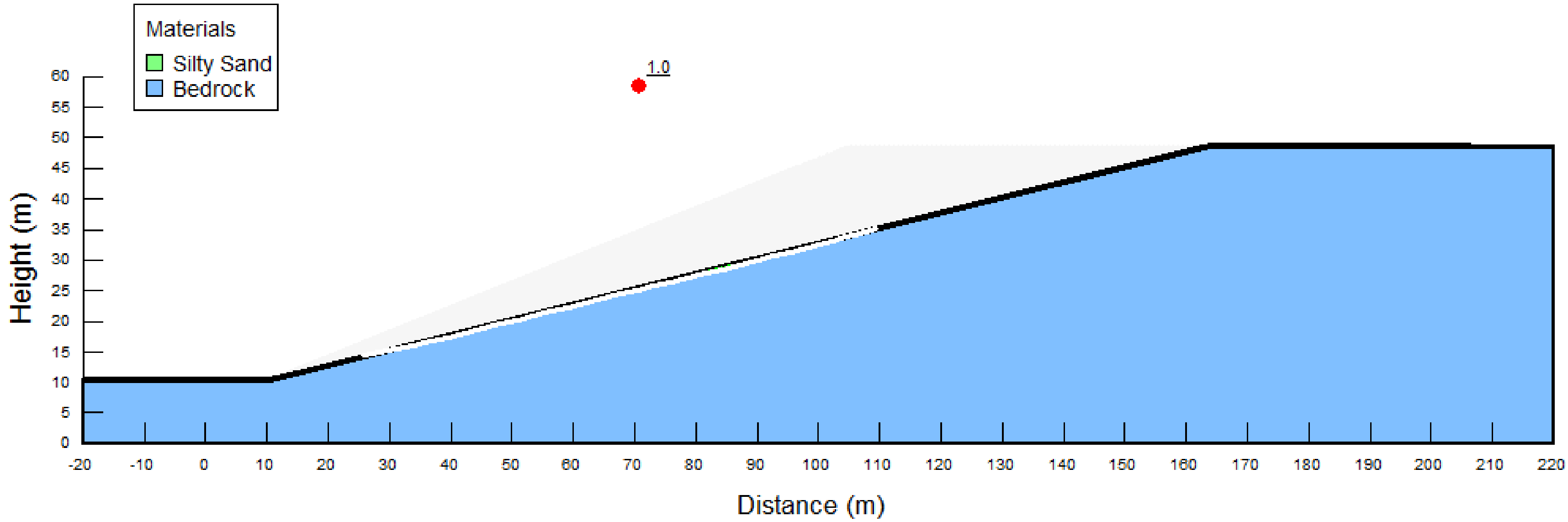

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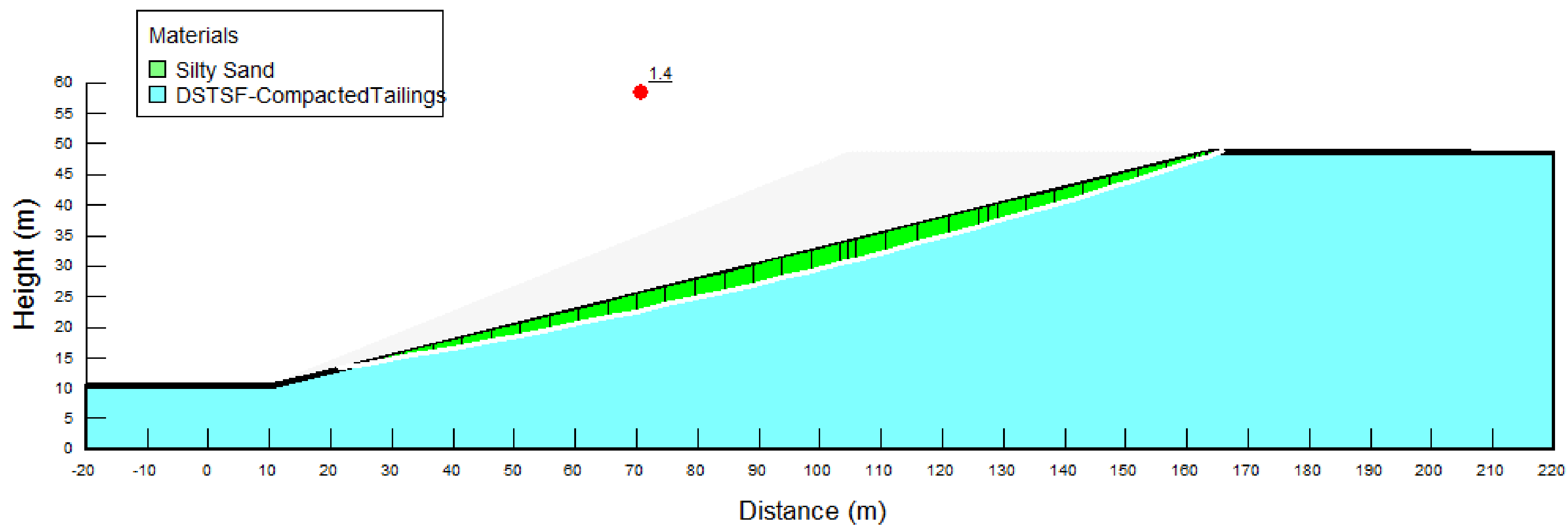

Scenario 2d

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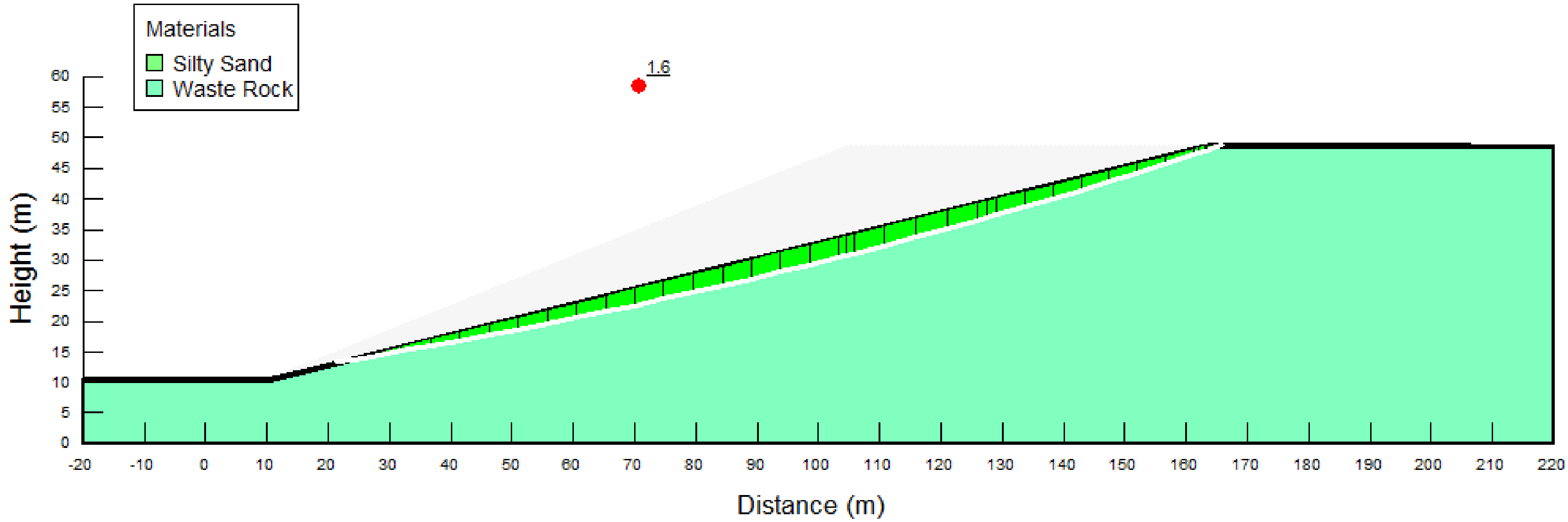

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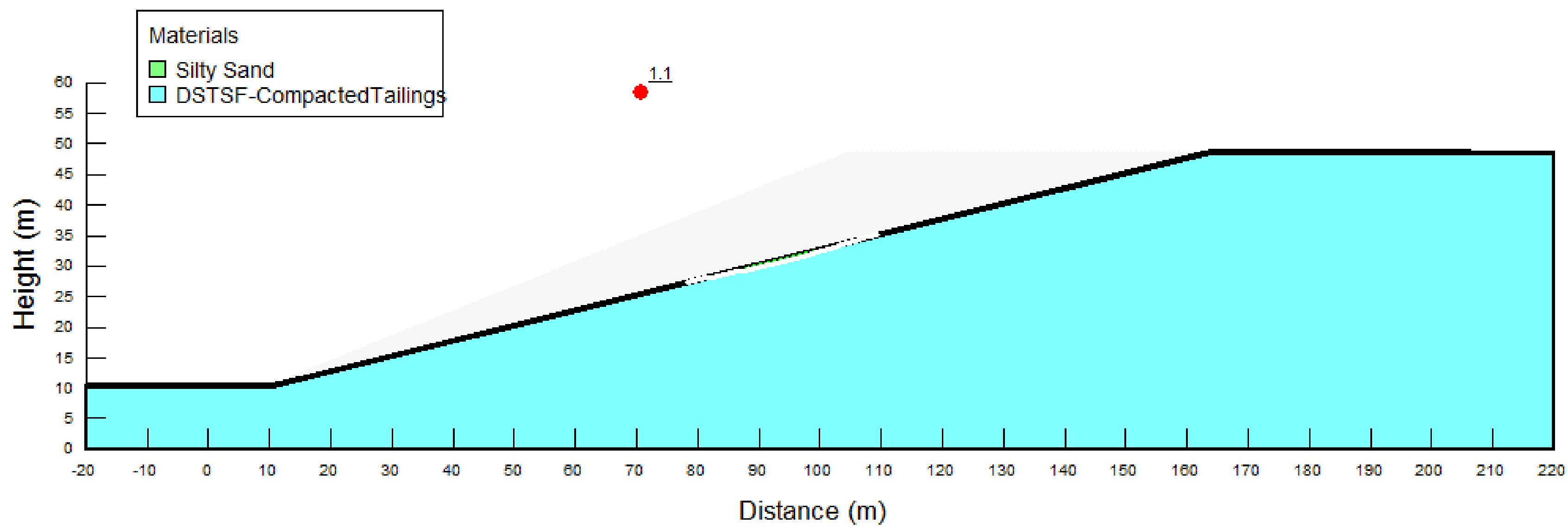

Scenario 2f

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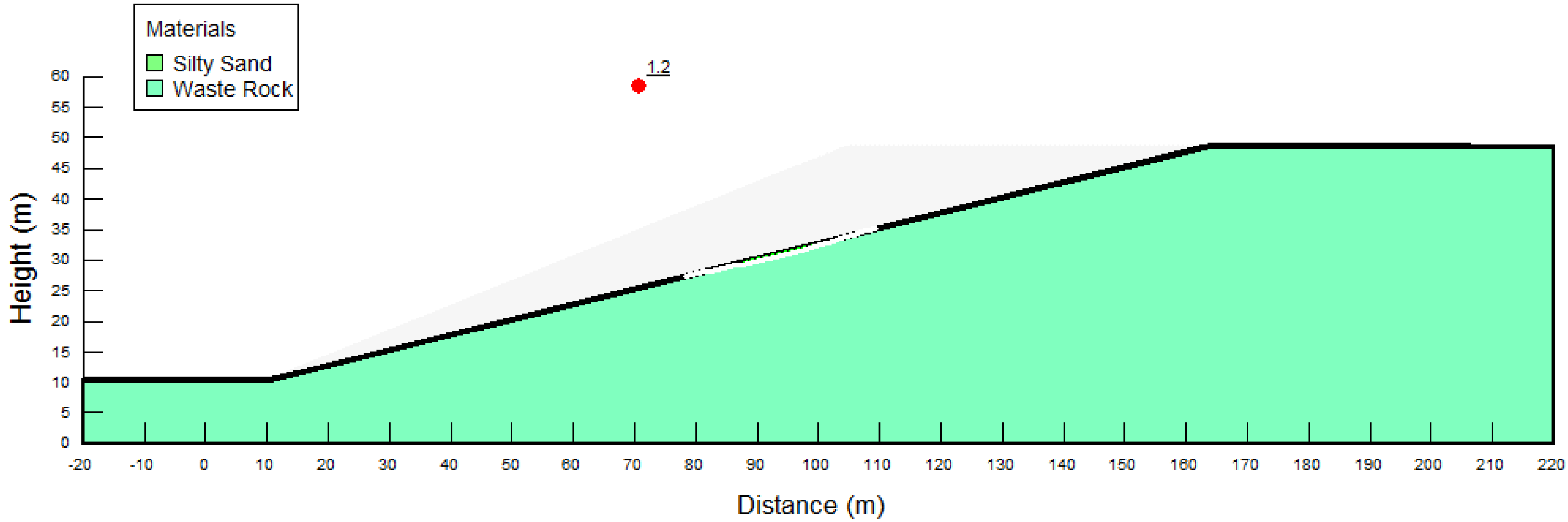

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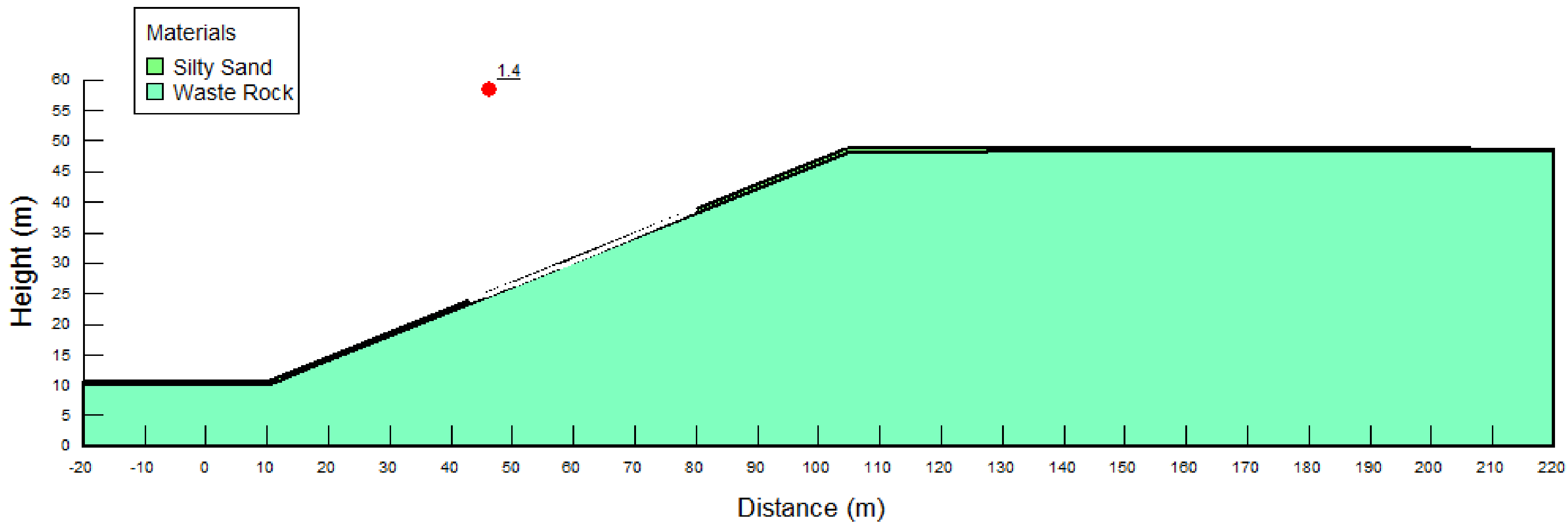

Scenario 2h

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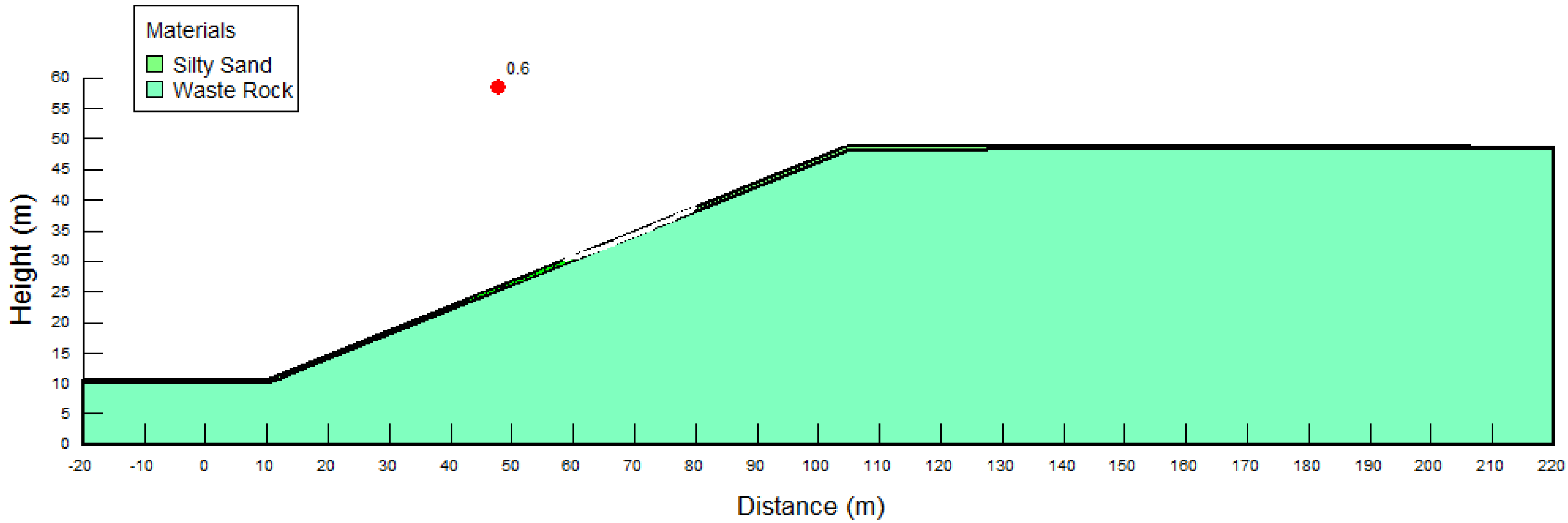

Scenario 1i

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Job No: 1CM002.049 Filename: StabilityAnalysis-Figures-1CM002-049_REV0-EK.pptx	Minto Closure Cover Design	Date: July 2016	Approved: EK	Figure: **12**

Appendix E – Minto Mine Preliminary Closure Cover Revegetation Plan

IEG
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MEMORANDUM

December 3, 2017

TO:	Erik Ketilson, SRK Consulting (Canada) Inc.
FROM:	Justin Straker
RE:	Update on revegetation planning for the Minto mine site, 2017
COPY:	

Please find below an update on activities completed with respect to revegetation planning at Minto in 2017. This update is not comprehensive, as some of our activities are still in progress, and will be reported later.

Site visit

A site visit was conducted on July 6, 2017, with Ryan Herbert (Capstone/Minto), Erik Ketilson and Dylan MacGregor (SRK), and Justin Straker (IEG) in attendance. The site visit focussed on surveying:

- non-mine areas as references for revegetation targets,
- established revegetation trials on Main Waste Dump (MWD);
- areas of natural regeneration on overburden stockpiles; and
- areas on the Dry-Stack Tailings Storage Facility (DSTSF) that are ready or nearly ready for revegetation.

Development of seed mixes for Minto for 2017/2018

SRK and Minto provided mapping of reclamation-ready or near-reclamation-ready areas for revegetation in 2017 and 2018. This mapping was then stratified as follows:

1. slopes versus plateaus – a primary goal of revegetation is to reduce erosion, where needed. Thus we identified sloped areas for erosion-control revegetation treatments and level areas where these treatments are not required; and
2. zonal(mesic) sites versus drier (subxeric-submesic) sites – the former occur on tailings substrates and north-facing slopes, while the latter occur on waste-rock substrates and south-facing slopes. Additional description of this mapping process is provided below.

An initial (rough) map of these revegetation classes is provided as Appendix A. Nomenclature for this map uses an adaptation of ecosites as described by Environment Yukon (2016 and 2017), where zonal sites are labelled as a site type containing the 01 and 30 ecosites (30 / 01), and drier sites are labelled as the 10 ecosite.

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This mapping indicated that approximately 42 ha of level/plateau areas and 38 ha of sloped areas could potentially be available for revegetation in the fall of 2017 or 2018. Seed mixes were designed for these areas based on the following principles, with the overarching objective that revegetation materials should be wholly or mostly made up of species native to the Yukon:

- **sloped areas** – the primary revegetation goal on these areas is erosion control, so the seed mix should be primarily composed of native grass species, seeded relatively heavily (35 kg/ha), with an additional component of annual ryegrass and alfalfa, to accelerate revegetation and reduce the amount of bare ground exposed to erosion. Alfalfa was included as it is the only native legume still listed as an acceptable species by the Yukon Revegetation Manual (Matheus and Omtzigt 2013).
- **level areas** – the primary revegetation goal on these areas is promotion of recovery towards pre-development ecosystems. For this reason, the primary revegetation strategy is natural regeneration, as this has been observed on many sites at Minto, and as the relatively small development footprint and proximity of non-mined seed sources facilitates this recovery mechanism. However, observations on the MWD revegetation trial and the naturally revegetating overburden stockpiles suggest that foxtail barley is present and readily able to colonize sites. This species is undesirable as a large component of revegetation, as it can cause problems for grazing wildlife after seed formation, as the long seed awns can get stuck in the mouth, nose, and eyes of grazing animals, potentially causing irritation and infection. Therefore a seed mix was developed for level areas at Minto, with the goal of providing some occupation of space to prevent full colonization by foxtail barley, but also of leaving space for natural colonization of these sites. The level-ground seed mix is composed solely of grass species native to the Yukon, applied at a rate lighter (20 kg/ha) than that used for the sloped areas.

Seed mixes were developed based on observations of species successful at the MWD, on similar observations from revegetation of the Grum Sulphide Cell at the Faro mine, and on recommendations from the seed supplier. Details on these seed mixes are found in the tables below.

Slope Seed Mix	% by Weight	Seeds/ lb	% by Seed Count
Agrostis scabra, **Ticklegrass**	0.50	4,000,000	7.45
Elymus glaucus, **Blue Wildrye (Smooth)**	15.00	131,000	7.32
Elymus lanceolatus, **Northern Wheatgrass**	15.00	167,000	9.33
Elymus trachycaulus, **Slender Wheatgrass**	25.00	145,000	13.50
Festuca saximontana, **Rocky Mountain Fescue**	10.00	679,000	25.29
Lolium multiflorum, **Annual Ryegrass (Diploid)**	20.00	217,000	16.17
Medicago sativa, **Alfalfa, Creeping Rooted**	12	226,798	10.14
Poa alpina, **Alpine Bluegrass**	2.00	1,000,000	7.45
Trisetum spicatum, **Spike Trisetum**	0.50	1,800,000	3.35
Total	100.000		100.00

The slope seed mix sown at 35 kg per hectare will spread approximately 200 seeds/ft^2.

Level Seed Mix	% by Weight	Seeds/ lb	% by Seed Count
Agrostis scabra, **Ticklegrass**	1.00	4,000,000	13.64
Elymus glaucus, **Blue Wildrye (Smooth)**	25.00	131,000	11.17
Elymus lanceolatus, **Northern Wheatgrass**	22.00	167,000	12.53
Elymus trachycaulus, **Slender Wheatgrass**	35.00	145,000	17.30
Festuca saximontana, **Rocky Mountain Fescue**	14.00	679,000	32.41
Poa alpina, **Alpine Bluegrass**	2.00	1,000,000	6.82
Trisetum spicatum, **Spike Trisetum**	1.00	1,800,000	6.14
Total	100.000		100.00

The level seed mix sown at 20 kg per hectare will spread approximately 125 seeds/ft^2.

Due to the multi-species nature of the seed mixes, and the amplitude of tolerance to soil-water conditions of the species in the mixes, different seed mixes are not proposed for zonal versus drier areas. Different treatments for these areas will be used any planting programs, as described below.

The seed mixes are designed to be co-applied with an NPKS fertilizer (18-18-18-1), with 50% of the nitrogen provided in a slow-release form (released over a 30 to 60 day period). Fertilizer was designed for an application rate of 125 kg/ha on sloped areas and 70 kg/ha on level areas. Fertilizer rates are designed to provide some nutrient support to establishing vegetation, but not so much nutrient, especially N, that the treatment will promote the rapid establishment of weedy species such as foxtail barley.

As the 2017 summer season developed at Minto, it became clear that seeding would not take place in the fall of 2017 on any of these areas. Seed and fertilizer mixes are now on site and ready for application in 2018.

Projection of post-closure ecosites

A preliminary projection of post-closure ecosites on the reclamation-ready landforms was completed using information on substrate physical properties, cover depth and characteristics, topography, and ecological landscape classification systems developed by Environment Yukon. This work extends previously introduced concepts of plant-available water-storage capacity (AWSC) and soil moisture regime (SMR) for mine reclamation (Straker et al., 2015a, 2015b). Results from these projections are that post-closure ecosystems are projected to have mesic (zonal) or submesic (drier) SMRs. Examples of edaphic projections for both mesic and submesic sites are included as Appendix B.

We attempted to translate the SMR projections to the Yukon Ecological Landscape Classification system using documents produced by Environment Yukon (2017 and 2016). However, detailed description of ecosites associated with SMR positions has to date only been completed for the Boreal Low Southern Lakes (BOLsl) subzone, whereas the Minto mine footprint is located in the Boreal Low Yukon Plateau North (BOLyn) subzone. Given the lack of better information, and the relative proximity and similarity of the BOLsl and BOLyn subzones, we have at this time adapted information and the classification approach from the BOLsl guide (Environment Yukon 2017) to Minto, modified for local site observations, primarily those contained in a 2013 Access Consulting Group report.

The majority of the currently projected post-closure ecosystems are in the drier (submesic) 10 ecosite, while a smaller proportion (on tailings substrates and north-facing slopes) is in the zonal (mesic) 30 / 01 ecosite. We provide additional detail on these ecosites below.

- **Drier submesic 10 ecosite –** these ecosystems are generally lodgepole-pine- and trembling-aspen-leading forests, with smaller components of grasses and willows. Other commonly observed species include white spruce, balsam poplar, alders, kinnikinnick, mosses, and lichens.
- **Zonal submesic 30 / 01 ecosite –** these ecosystems are also pine- and aspen-leading forests with willow, but also have larger components of species associated with greater amounts of soil water, such as spruce and alder. Other commonly observed species include Alaskan birch, soapberry, *Vaccinium* and *Ledum* species, lupine, grasses, mosses, and lichens.

These ecosite projections will be used to develop revegetation treatments to supplement seeding as necessary. The primary reason to use these treatments will be to accelerate

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revegetation, to establish species important for end land uses that are not establishing through natural regeneration, and/or for specific purposes such as additional erosion control around drainage channels. As discussed above, these projections and associated ecosite information are preliminary, being a transposition from the BOLsl ecosite classification, and based on sparse information on pre-development conditions at Minto. They will be refined as we continue to develop our projection system, as we acquire additional information on pre-development/adjacent (reference) ecosystems at Minto, and as the Yukon Ecological Landscape Classification system advances.

Closure

We trust this memo meets your information requirements at this time, and thank SRK for IEG's ongoing involvement with the Minto reclamation program. To discuss the contents of this memo and/or work required going forward, please do not hesitate to contact me at jstraker@iegconsulting.com, or at 250 701 0600.

References

Access Consulting Group. 2013. Minto ecosystems and vegetation baseline report – YESAB Project Proposal Phase V-VI. Internal report prepared for Minto Exploration Ltd.

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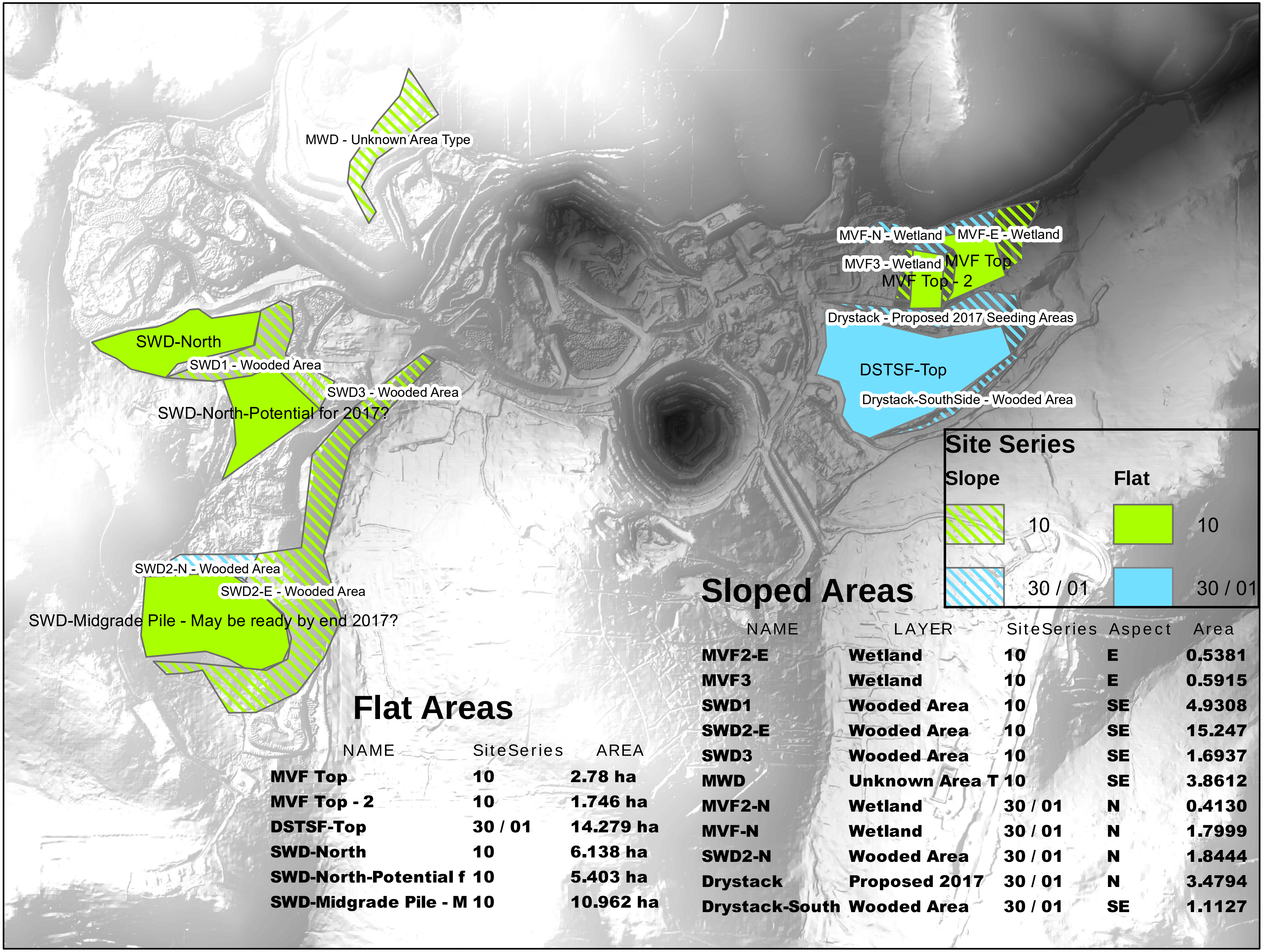
Appendix A

Mapped revegetation units



Sloped Areas

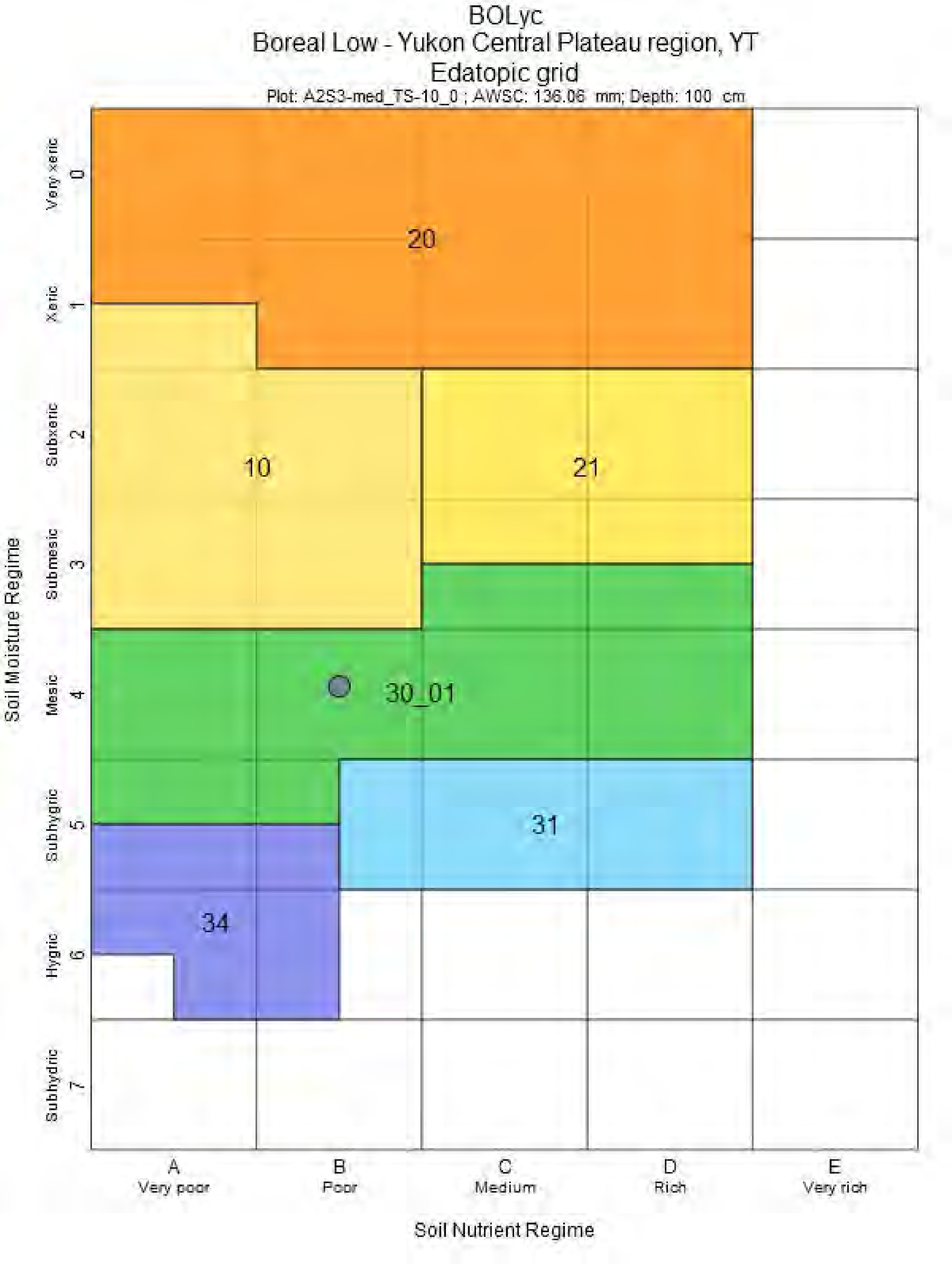
NAME	LAYER	SiteSeries	Aspect	Area
MVF2-E	Wetland	10	E	0.5381
MVF3	Wetland	10	E	0.5915
SWD1	Wooded Area	10	SE	4.9308
SWD2-E	Wooded Area	10	SE	15.247
SWD3	Wooded Area	10	SE	1.6937
MWD	Unknown Area T	10	SE	3.8612
MVF2-N	Wetland	30 / 01	N	0.4130
MVF-N	Wetland	30 / 01	N	1.7999
SWD2-N	Wooded Area	30 / 01	N	1.8444
Drystack	Proposed 2017	30 / 01	N	3.4794
Drystack-South	Wooded Area	30 / 01	SE	1.1127

Flat Areas

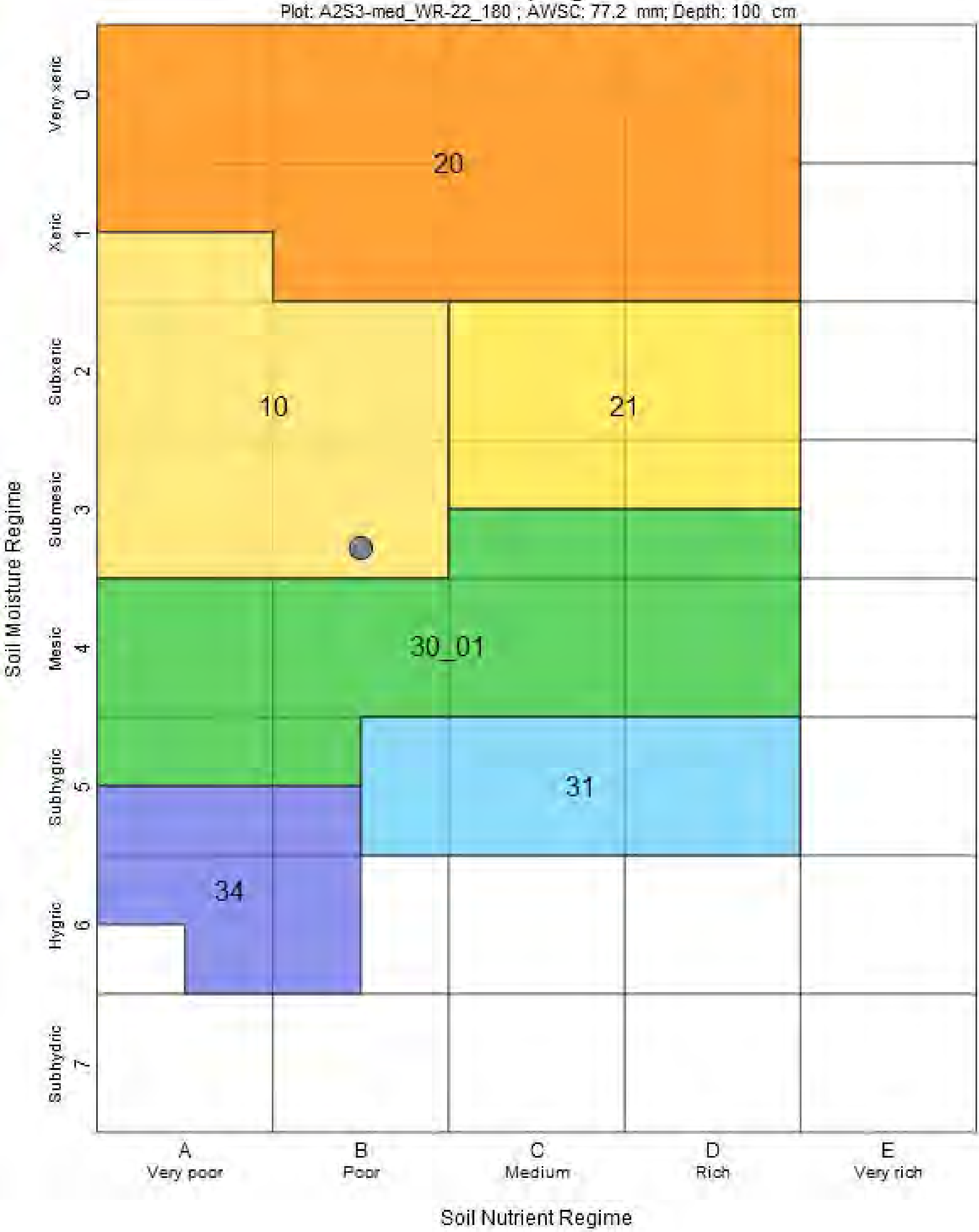
NAME	SiteSeries	AREA
MVF Top	10	2.78 ha
MVF Top - 2	10	1.746 ha
DSTSF-Top	30 / 01	14.279 ha
SWD-North	10	6.138 ha
SWD-North-Potential f	10	5.403 ha
SWD-Midgrade Pile - M	10	10.962 ha

Appendix B

Example edaphic-grid projections for mesic and submesic post-closure ecosites


BOLyc
Boreal Low - Yukon Central Plateau region, YT
Edatopic grid
Plot: A2S3-med_TS-10_0 ; AWSC: 136.06 mm; Depth: 100 cm
20
10
21
30_01
31
34
Soil Moisture Regime
0 Very xeric
1 Xeric
2 Subxeric
3 Submesic
4 Mesic
5 Subhygric
6 Hygric
7 Subhydric
A Very poor
B Poor
C Medium
D Rich
E Very rich
Soil Nutrient Regime

BOLyc
Boreal Low - Yukon Central Plateau region, YT
Edatopic grid



Appendix F – Minto Closure Cover Design – Hydrotechnical Designs for Engineered Landforms

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Memo

To:	File	**Client:**	Minto Explorations Ltd.
From:	Erik Ketilson, MEng, PEng	**Project No:**	1CM002.049
Reviewed by:	Dylan MacGregor, MSc, PGeo	**Date:**	January 29, 2018
Subject:	Minto Closure Cover Design – Hydrotechnical Designs for Engineered Landforms		

1 Introduction

SRK Consulting (Canada) Inc. (SRK) is undertaking an update to the Minto Closure Plan, which includes updated landform grading designs for the waste facilities, and consideration to shedding water off of these structures. Several areas of the site require varying degrees of hydrotechnical features to collect and convey storm water over the covers. Wide, shallow channels (swales) have been sized for the main engineered landforms based on catchment area and grade. The main engineered landforms under consideration include the Southwest Waste Dump (SWD), the Ridgetop Dump (RTD), the Rigetop North Pit Tailings Management Facility (RNPTMF), the Ridgetop South Pit Backfill Dump (RSPBD), the Dry Stack Tailings Storage Facility (DSTSF), the Mill Valley Fill (MVF), the Main Waste Dump and Main Waste Dump and Expansion (MWD), the Main Pit Dump (MPD), and the Area 118 Pit Backfill Dump (Area 118). This memo summarizes the design process and presents the recommended sizing of the swale designs for each area.

2 Watershed Analysis

Watershed areas were delineated for each of the eight main landforms based on closure configurations as presented in the Updated Closure Cover Design Report (SRK, 2018). Each landform, with the exception of Area 118, was then subdivided into smaller watershed areas that will collect water independently of one another to shed water off the top of the structure, and then into a channel directed down-slope. The areas and their general flow directions are presented in Figure 1.

3 Hydrology

Site Hydrology was updated by SRK in 2016; complete hydrological details are included in The Minto Mine – Closure Water Conveyance System Design Update Report (SRK, 2016). The updated flow vs. watershed area relationships yield substantially greater flows than in previous site hydrological assessments completed by SRK and Janowicz (SRK, 2016). The increase is due in part to the fact that for return periods greater than 1:5 year event, Environment Canada's hydrometric station, the Little South Klondike River below Ross Creek presents the highest unit peak. For this reason, the Little South Klondike River below Ross Creek hydrometric station was selected for calibration purposes in order to generate a conservatively high estimate for unit peak flows.

The swales were designed to accommodate a 1 in 200 year, 24 hour storm event consistent with the approach presented by SRK (2016). The flows expected on each watershed are presented in Table 3-1, with watershed areas illustrated on Figure 1.

Table 3-1: Watershed Areas and Design Flow Rates

Area	ID	Contributing Area (m^2)	1 in 200 Year Flow Rate (m^3/s)
SWD	A1	11,500	0.09
	A2	11,170	0.09
	A3	20,830	0.15
	A4	18,840	0.13
	A5	12,050	0.09
	A6	17,360	0.13
	A7	111,110	0.63
	A8	19,540	0.14
	A9	36,800	0.24
	A10	32,960	0.22
	A11	59,870	0.37
RTD	A12	34,820	0.23
	A13	28,040	0.19
	A14	7,380	0.06
DSTSF	A15	30,490	0.20
	A16	22,100	0.15
	A17	20,540	0.15
	A18	63,160	0.39
	A19	15,310	0.11
MVF	A20	32,450	0.22
	A21	120,380	0.68
	A22	55,470	0.34
MWD	A23	49,180	0.31
	A24	27,240	0.19
	A25	78,600	0.47
	A26	102,770	0.59
MP	A27	26,120	0.18
A118	A28	22,670	0.16
	A29	31,780	0.21
	A30	7,790	0.06
RNPTMF	A31	110,600	0.63
RSPBD	A32	27,040	0.18

Source: 2018-Minto Channel Flow_Rev03-jg-ek.xlsx

4 Swale Designs

Drainage swales have been designed for the top surfaces and slopes of the seven main engineered landforms. The channel depths were determined using Manning's Equation, and were then increased by a factor of 2 to account for the potential effects that ice may have on flow within the channel. This approach is consistent with other sites in the Yukon, where there is a need to account for increased channel capacity and quantification of the increased capacity is challenging.

The cross sections of the swales on the top surfaces are trapezoidal, primarily with a base width of 2 m and 10H:1V side slopes. Each swale was designed with a variable grade, representative of the anticipated grade of the final closure cover design, the grades are presented in Table 4-1. A Manning's "n" in each channel of 0.035 was applied, which is representative of roughness due to the presence scattered brush and heavy weeds in flood plains (Bedient et al, 2008).

The cross sections of the swales on the slopes are trapezoidal, with base widths equal to those of the swales on the top surfaces, but with 3H:1V side slopes. Each swale was designed with a variable grade, representative of the closure cover design, the grades are presented in Table 4-2. A Manning's "n" in each channel of 0.040 was applied, which is representative of roughness due to the presence a bottom with gravels, and cobbles in mountain streams (Bedient et al, 2008).

The dimensions of each channel are indicated in Table 4-1 for the facility tops, and Table 4-2 the slopes. Flow velocity is also included in the table.

Table 4-1: Channel Dimensions and Flow Velocities for Facility Tops

Area	ID	Channel Dimensions				Channel Dimensions for n=0.035 - vegetation				
		Slope (%)	Length (m)	Bottom Width (m)	Side Slopes (H:V)	Depth of Flow (m)	Allotment for Ice Formation (m)	Total Depth (m)	Top Width (m)	Flow Velocity (m/s)
SWD	A1	1.5%	100	2.0	10	0.07	0.07	0.13	4.7	0.49
	A2	1.5%	85	2.0	10	0.07	0.07	0.13	4.6	0.49
	A3	2.2%	110	2.0	10	0.08	0.08	0.16	5.2	0.66
	A4	2.0%	110	2.0	10	0.08	0.08	0.16	5.1	0.62
	A5	1.0%	85	2.0	10	0.08	0.08	0.15	5.0	0.44
	A6	1.0%	110	2.0	10	0.09	0.09	0.18	5.6	0.48
	A7	1.5%	85	2.0	10	0.19	0.19	0.37	9.5	0.88
	A8	1.5%	115	2.0	10	0.09	0.09	0.17	5.4	0.57
	A9	0.5%	140	2.0	10	0.15	0.15	0.30	8.1	0.45
	A10	4.5%	140	2.0	10	0.08	0.08	0.16	5.3	0.96
	A11	2.0%	300	2.0	10	0.13	0.13	0.26	7.3	0.84
RTD	A12	0.2%	300	2.0	10	0.19	0.19	0.37	9.4	0.32
	A13	2.5%	120	2.0	10	0.09	0.09	0.18	5.5	0.75
	A14	0.2%	85	2.0	10	0.09	0.09	0.19	5.7	0.22
DSTSF	A15	1.5%	140	2.0	10	0.11	0.11	0.21	6.2	0.64
	A16	1.5%	140	2.0	10	0.09	0.09	0.18	5.6	0.59
	A17	2.5%	250	2.0	10	0.08	0.08	0.15	5.0	0.69
	A18	2.0%	225	2.0	10	0.14	0.14	0.27	7.4	0.85
	A19	3.5%	105	2.0	10	0.06	0.06	0.12	4.4	0.72
MVF	A20	2.5%	200	2.0	10	0.09	0.09	0.19	5.8	0.78
	A21	1.5%	165	2.0	10	0.19	0.19	0.39	9.7	0.89
	A22	1.5%	125	2.0	10	0.14	0.14	0.28	7.5	0.74
MWD	A23	1.5%	170	2.0	10	0.13	0.13	0.26	7.2	0.72
	A24	5.5%	175	2.0	10	0.07	0.07	0.14	4.7	0.98
	A25	2.5%	180	2.0	10	0.14	0.14	0.28	7.6	0.97
	A26	2.0%	125	2.0	10	0.17	0.17	0.34	8.7	0.95
MP	A27	1.0%	150	2.0	10	0.11	0.11	0.22	6.4	0.53
A118	A28	3.0%	65	2.0	10	0.08	0.08	0.15	5.0	0.75
	A29	5.0%	50	2.0	10	0.08	0.08	0.16	5.1	0.98
	A30	5.0%	25	2.0	10	0.04	0.04	0.08	3.6	0.67
RNPTMF	A31	0.5%	140	2.0	10	0.24	0.24	0.48	11.7	0.59
RSPBD	A32	1.0%	80	2.0	10	0.11	0.11	0.22	6.4	0.54

Source: 2018-Minto Channel Flow_Rev03-jg-ek.xlsx

Table 4-2: Channel Dimensions and Flow Velocities for Facility Slopes

Area	ID	Channel Dimensions				Channel Dimensions for n=0.040 - gravel to cobble sized rip rap				
		Slope (%)	Length (m)	Bottom Width (m)	Side Slopes (H:V)	Depth of Flow (m)	Allotment for Ice Formation (m)	Total Depth (m)	Top Width (m)	Flow Velocity (m/s)
SWD	A1	10.5%	130	2.0	3	0.04	0.04	0.04	2.3	0.95
	A2	21.0%	85	2.0	3	0.03	0.03	0.07	2.4	1.17
	A3	19.5%	100	2.0	3	0.05	0.05	0.10	2.6	1.40
	A4	10.0%	350	2.0	3	0.06	0.06	0.11	2.7	1.10
	A5	19.0%	80	2.0	3	0.04	0.04	0.07	2.4	1.17
	A6	12.0%	110	2.0	3	0.05	0.05	0.10	2.6	1.14
	A7	22.0%	150	2.0	3	0.11	0.11	0.22	3.3	2.45
	A8	19.0%	185	2.0	3	0.05	0.05	0.10	2.6	1.36
	A9	10.5%	284	2.0	3	0.08	0.08	0.16	2.9	1.38
	A10	8.3%	100	2.0	3	0.08	0.08	0.16	3.0	1.23
	A11	20.0%	115	2.0	3	0.08	0.08	0.17	3.0	1.97
RTD	A12			NA				NA		
	A13			NA				NA		
	A14			NA				NA		
DSTSF	A15			NA				NA		
	A16			NA				NA		
	A17 A18	17.0%	65	2.0	3	0.10	0.10	0.21	3.2	2.03
	A19			NA				NA		
MVF	A20			NA				NA		
	A21	25.0%	55	2.0	3	0.11	0.11	0.22	3.3	2.62
	A22	30.0%	40	2.0	3	0.07	0.07	0.14	2.9	2.19
MWD	A23	30.0%	35	2.0	3	0.07	0.07	0.13	2.8	2.11
	A24	33.0%	40	2.0	3	0.05	0.05	0.10	2.6	1.81
	A25 A26	22.5%	75	2.0	3	0.14	0.14	0.28	3.7	2.85
MP	A27	42.0%	35	2.0	3	0.04	0.04	0.09	2.5	1.92
A118	A28	40.0%	150	2.0	3	0.04	0.04	0.08	2.5	1.81
	A29	35.0%	200	2.0	3	0.05	0.05	0.10	2.6	1.93
	A30	10.0%	200	2.0	3	0.04	0.04	0.07	2.4	0.83
RNPTMF	A31			NA				NA		
RSPBD	A32	10.0%	65	2.0	3	0.07	0.07	0.14	2.8	1.23

Source: 2018-Minto Channel Flow_Rev03-jg-ek.xlsx

5 Conclusion

As stated by SRK (2016), engineered designs to reduce erosion within the swales may be required for flow velocities greater than 1 m/s (engineered designs could include rip rap, other armouring, or velocity reducing features within the swale). Engineered designs to reduce erosion in cases where flow velocities are less than 1 m/s are not required; in these scenarios, short term erosion control support practices, such as the use of rolled erosion control products and/or hydroseeding is sufficient to reduce erosion until surface vegetation is established.

The swales for the facility tops have a base width of 2 m and are 0.08 to 0.48 m deep and have 3.6 to 11.7 m top widths. All designs were completed to equal a flow velocity of 1.0 m/s or less such that channel protection can be achieved using surface vegetation.

The swales for the facility slopes have base widths equal to the facility tops. Total depths were estimated to be between 0.04 m and 0.28 m deep, and have top widths ranging between 2.26 m and 3.68 m. Nearly all of the flow velocities are greater than 1.0 m/s, while considering a base consisting of gravel and cobble rip rap protection. Therefore, detailed design of these structures should account for appropriate riprap protection, with sizing of the rip rap to be completed at that time.

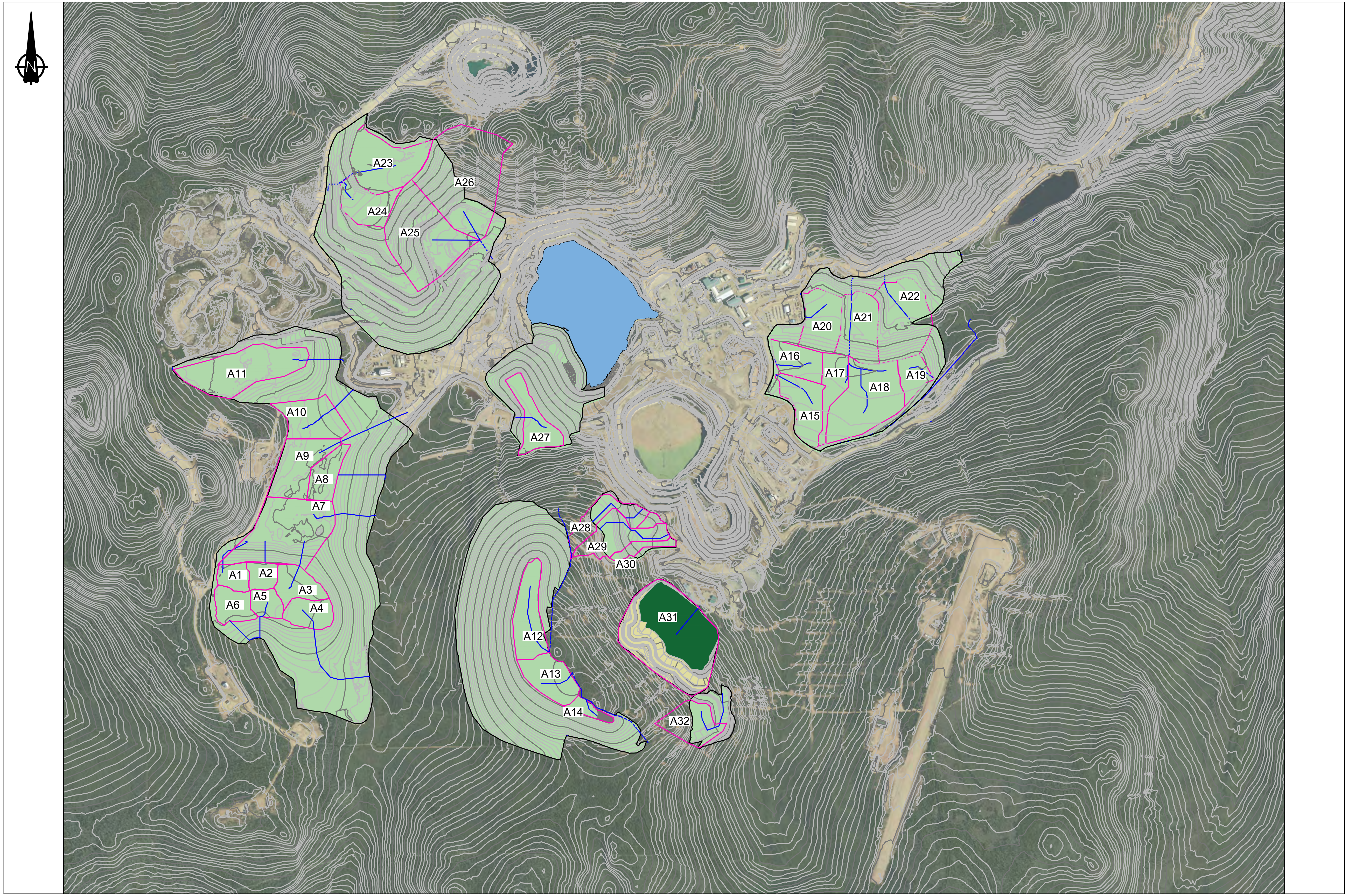
6 References

Bedient, P; Humber, W.; Vieux; B. 2008. Hydrology and Floodplain Analysis – 4th Edition. Textbook. Prentice-Hall, Inc. Upper Saddle River, NJ.

SRK Consulting, 2016. Minto Mine – Closure Water Conveyance System Design Update Report. Prepared for Minto Explorations Ltd. SRK Consulting (Canada) Inc. Project No. 1CM002.042. June 2016.

SRK Consulting, 2018. Updated Closure Cover Designs for the Minto Mine 2018 Reclamation and Closure Plan. Prepared for Minto Explorations Ltd. SRK Consulting (Canada) Inc. Project No. 1CM002.049. January 2018.

Figures



LEGEND

- Watershed
- A12 Watershed Reference Number
- Proposed Flow Alignment
- Subaerial Tailings Cover
- Cover Application Area
- Open Pit Slopes
- Water

NOTES

1. Contours shown at 2.0m intervals.
2. Orthophoto date August, 2017 and provided by Minto.
3. This figure should be read in conjunction with report Minto Closure Cover Design - Hydrotechnical Designs for Engineered Landform. Dated January, 2018.
4. Waste facility grading is based on designs prepared for the Updated Closure Cover Design for the Minto Mine 2018 Reclamation and Closure Plan. Dated January, 2018.

0m 100 200 300 400 500 600

srk consulting

capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.

SRK Project NO.: 1CM002.049	Minto Mine, Yukon	Hydrotechnical Designs for Covers
FILE NAME: 1CM002.049_2018RCP-Regrade-Catchments_R1.dwg		Watershed Areas
		DATE: January 2018 · APPROVED: EK · FIGURE: 01

Appendix E4
Closure Landform Design and Reclamation Landform Units for the Minto Mine

Closure Landform Design and Reclamation Landform Units for the Minto Mine

Prepared for

Minto Explorations Ltd.

Prepared by

SRK Consulting (Canada) Inc.
1CM002.031
May 2016

Closure Landform Design and Reclamation Landform Units for the Minto Mine

May 2016

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Project No: 1CM002.031

File Name: RLU_SiteWideLandformDesign_1CM002-031_20160520_eh_im_dbm

Table of Contents

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1 Introduction

1.1 Site Description

The Minto Mine is a high-grade copper mine located in the Yukon, approximately 240 km north of Whitehorse. The mine site occupies the valley in the upper reaches of Minto Creek, a tributary on the west side of the Yukon River, about 9 km from the mouth. Operations are ongoing at this time (2016) and began in October 2007. Three pits have been completed to date: the Main Pit, the Area 118 Pit, and the Area 2 Stage 2 Pit.

Initially tailings were deposited in the Dry Stack Tailings Storage Facility (DSTSF) which was completed in 2012. Currently tailings and process water are managed in the Main Pit Tailings Facility (MPTF) and the Area 2 Pit Tailings Management Facility (A2PTMF). Various waste rock storage facilities exist across the site including the Main Waste Dump (MWD), Main Waste Dump Expansion (MWDE), the Main Pit Dump (MPD), the Southwest Waste Dump (SWD), the Area 118 Dump, and the Mill Valley Fill (MVF) currently undergoing the Stage 2 expansion.

1.2 Purpose of this Report

Some mine structures are complete (e.g. DSTSF) or are nearing completion (e.g. Main Waste Dump Expansion) and are in need of reclamation designs. In order to facilitate the reclamation of various structures across the site, Minto Explorations Ltd. (Minto) has retained SRK Consulting (Canada) Inc. (SRK) to prepare general landform design concepts specific to the Minto site, and to define Reclamation Land Units (RLUs) that will serve as the building blocks for establishing closure landforms across the site.

This report documents the work completed to develop site-specific landform design concepts and RLU designations for the Minto Mine.

1.3 Scope of Work

As part of the larger project scope, site reconnaissance was completed in 2014. Based on the information gleaned from the site visit, coupled with other relevant information such as closure cover soil availability and type, SRK has prepared general landform design concepts or “rules” specific to the overall Minto site. The purpose is to develop landform design concepts that will ensure geotechnical stability and landforms that have a natural appearance that fits with the surrounding landscape, and that drains surface water, while minimizing the potential for erosion. Reclamation Land Units (RLU) will also be developed for the site. Each RLU will have specific function(s) and will be used in future design stages as the guiding principles for establishing a closure landform.

This report documents the landform design concepts and RLUs and is the deliverable for this task. Some cost considerations are also provided, together with landform monitoring recommendations.

It is intended that this work will become the basis for all future site reclamation and development planning. This document should be considered a “live” document, as it is expected to be adjusted as progressive reclamation takes place and improvements are made based on lessons learned along the way.

1.4 About this Report

This Report is organised into seven sections, excluding the references section. Following the introduction (Section 1), relevant site background description is provided in Section 2. The technical analysis part of the report is comprised of three sections, with Section 3 presenting the soil erosion analysis completed, Section 4 providing the methodology and results of the conceptual landform design while Section 5 presents a description of the RLU designations. The erosion analysis and the landform design process are equally important in informing the RLU descriptions, which in turn will become an important part of final reclamation planning for Minto Mine. Section 6 discusses the RLU designations and their application to closure planning at Minto.

2 Site Background

The general conditions at the Minto Mine site are discussed in a number of public documents related to permitting, operation, expansion and closure of the mine (Access 2013, Access 2014, SRK 2014). This section of the report will therefore focus primarily on those topics which are of direct relevance.

2.1 Overburden

Overburden thickness across the site is closely correlated with geomorphological features. Near topographic highs, there is little to no overburden, with increasing overburden thickness down valley slopes. The thickest deposits are found in the valley bottoms and along the paleochannel, which is offset to the south from the Minto Creek valley bottom and identified on the south side of the Main Pit and north side of the DSTSF (SRK 2014).

Generally, ridge tops are dominated by sandy residual soils grading to weathered bedrock. Fine weathered products have been washed downslope, and have also been deposited by glacial, periglacial and aeolian processes, which has resulted in accumulations of finer sandy silts and clays within the valleys.

2.2 Permafrost

Minto Mine is located in a discontinuous permafrost region. In general, the south facing slopes are unfrozen, while north facing slopes and valley bottoms contain permafrost. Where permafrost is present it is generally warm, with temperatures close to -0.5ºC. The active layer is variable ranging from less than 1 m to about 3 m in thickness (SRK 2014). The general distribution of permafrost on the site is illustrated in Figure 1.

Ice content within the overburden ranges from non-visible to 30% excess ice, although ice lenses are common and massive ice up to 4 m thick occurs, particularly near the bedrock surface within the paleochannel. The depth of permafrost is variable, but in certain locations it is known to extend down to the base of the paleochannel.

2.3 Vegetation

Vegetation on site is dominated by mixed Willows and Trembling Aspen, with fire history (and related vegetative succession) exerting a very strong influence on the present distribution of plant species. Lodgepole Pine is a later successional species that will dominate mid and upper well drained slopes. White and Black Spruce seedlings are common in the undergrowth and will likely outgrow the pine and aspen communities, especially on northern aspects and along slope toes and valley bottoms. Small grassland areas exist along ridge-tops and steep south-facing slopes as these areas do not retain enough moisture to support tree growth. Much of the planned mine expansion is along ridgetops and mid-slopes, with vegetation in these areas being mostly comprised of willow, aspen, pine, and understory seedling growth. No rare or endangered plants were found during surveys of the planned impact areas (Access 2013).

It should be noted that vegetation trials were conducted at Minto until 2015. Vegetation test plots on the sloped face of the Main Waste Dump were being actively managed and assessed annually and findings from this trial program will be transferred to more progressive reclamation efforts at other areas of the site. As trial results become available, knowledge relating to growth media, seed mixes, vegetation establishment, and vegetative erosion control will evolve and reclamation land unit designations will be revised accordingly (Access 2014).

3 Erosion Analysis

Land impacted by mining is often characterized by steep slopes as illustrated in Figure 2. Waste rock dumps are usually constructed by end-dumping from slope crests such that the dump material lies at its natural angle of repose. Dump faces constructed in this manner often have a high erosion potential due to the uniformly steep and relatively long slopes. In cases where soil covers are required to achieve the long-term closure objectives, the slope of these dump faces needs to be reduced to allow the construction of a soil cover.

Even soil covers constructed on regraded slopes (typically much shallower than angle of repose) may exhibit excessive erosion that could, under certain conditions, compromise the overall performance. It is therefore important to identify if erosion could become a failure mechanism. This is typically done through erosion modelling, as described below.

3.1 Erosion Assessment Methodology

Various numerical methods are in use worldwide to determine soil loss on an inclined slope, most originating from agriculture and soil sciences. One of the most commonly used models in North America is the USLE model, short for Universal Soil Loss Equation, which was developed using runoff and soil loss data from over 10,000 plot years at 49 locations across the US in the 1950s (USDA 1978). The USLE was developed to predict the long term average annual rate of erosion on a sloped field and is based on a combination of rainfall pattern, soil type, topography, crop type, and management practices. One of the major limitations of this approach is that it assumes sheet erosion as the only erosional mechanism, whereas rill erosion is typically predominant for recently placed soil cover material on slopes.

Although rudimentary in its approach, the USLE method was chosen for its simplicity, as the intent here was to demonstrate relative sensitivity of slope erosion to the various environmental factors affecting the slope, rather than compute a highly accurate soil loss estimate. Using a rigorous erosion prediction method was necessary to compare the various slope configurations and identify the range in which each input parameter will exert a strong influence on performance.

The erosion assessment approach may be re-evaluated at a later stage (with consideration given to using a more sophisticated model), when specific slope designs will be completed for the distinct mine waste facilities.

An estimate of the potential erosion from slopes with a soil cover at gradients ranging from 2.5H:1V to 6H:1V was completed using the USLE. At the Minto site, conservation measures similar to those used in farm planning can be applied to evaluate closure options among landform designs, and were therefore considered in the erosion estimates.

The governing equation is presented below:

$$A = R * K * LS * C * P \qquad \text{[Eq. 1]}$$

Where;
R = rainfall and runoff factor (dimensionless)
K = soil erodibility factor (t/Ha)
LS = slope length and steepness factor (dimensionless)
C = crop/vegetation management factor (dimensionless)
P = support practice factor (dimensionless)

The slope length and steepness factor (LS) is calculated using the following equation:

$$LS = (0.065 + 0.0456S + 0.006541S^2)*(L/22.1)^X$$

Where:
S = slope steepness (%)
L = slope length (m)
X = 0.2 (S<1%), 0.3 (1≤S<3), 0.4 (3≤S<5), 0.5 (≥5)

3.2 USLE Parameter Selection

Table 1, at the end of this section, summarizes the parameters used in the USLE calculation. For the rainfall and runoff factor, it was decided to use a rainfall and runoff factor from an area in the United States of America with a similar mean annual precipitation (MAP). The Minto project has a MAP of approximately 350 mm. Areas in the mid-west US with comparable MAP have rainfall and runoff factors of 75 or less. It has been assumed that a value of 75 is appropriate for the Minto site.

For the soil erodibility factor, it was assumed that cover material will be sourced from the reclamation overburden dump (ROD) or from stripping related to the Phase V/VI pit development activities. On average, the ROD material has an average of 17% gravel, 46% sand, 27% silt, and 10% clay (SRK 2013). Removing the gravel proportion, this equates to normalized sand, silt, and clay percentages of 55, 33, and 12, respectively, which means the fine portion of the material falls into the Sandy Loam soil category and is on the fine end (Figure 3 (a)). Several sources provide soil erodibility factors for loam soils that fit this general soil type. A factor of 0.54 was chosen as the average between sandy loam (0.31) and loam (0.71) (Stone and Hilborn 2015). However, the factor was varied for different cover soil types as illustrated in Figure 3 (b).

Slope-length and slope steepness (gradient) were varied in the calculations to allow a comparison of the calculated erosion rates at different slope lengths and gradients. Slope lengths and gradients will vary on reclaimed landforms as they vary across the unimpacted areas of the site, so the analysis focused on slopes between 22° (2.5H:1V) and 9° (6H:1V) with lengths between 20 m and 200 m. Figures 3 (c) and (d) illustrate the change in calculated erosion values for this range of slope lengths and gradients.

The crop and vegetation factor is a reduction factor based on the type of erosion protection given by particular vegetation types, ranging from 0.01 for anti-erosion blankets and mats to 1.0 for no vegetation. For mine reclamation it is important to understand the relationship between erosion and different levels of vegetation establishment. Figure 3 (e) includes an analysis of erosion based on vegetation factors covering the entire available USLE model input range, from no vegetation to purpose-built anti-erosion mats. This range also includes trees, bushes, straw mulch, and grass.

The support practice factor is included to characterize the effect of particular cover surface treatment. A smooth surface will increase erosion as it allows surface water to move with maximum energy, while tracked surfaces provide natural kinetic energy reduction due to micro-scale step pools that help dissipate energy. The support practice factor for agricultural practices like cross-slope farming and contour farming (analogues for cross-slope tracking or ripping) ranges between 0.25 and 1.0. However, since mine reclamation does not typically involve annual re-work of surfaces, as is common with farm applications, it was assumed that no improvements will be maintained in the long term and the support practice factor has been set to 1.0 for all analyses.

Table 1: Parameters Selected in USLE Calculation

USLE Factor	Base Case	Variation
Rainfall and Runoff Factor – R (dimensionless)	75	N/A
Soil Erodibility Factor – K (t/ha)	0.54	0.07 to 0.74 for different soil types.
Slope Length and Steepness – LS (dimensionless)	18.83 (100 m slope length and 3:1 slope)	5.62 to 26.63 for slope lengths between 20 and 200 m and slopes from 2.5:1 to 6:1.
Crop/Vegetation Management Factor – C (dimensionless)	0.25 (no cover and no tillage)	0.005 to 0.25 for different vegetation/cover treatments from erosion blankets to trees to no cover. Tillage not considered in range.
Support Practice Factor – P (dimensionless)	1	N/A

3.3 USLE Analysis Results

A base case for erosion at the Minto site was defined in order to allow comparison of erosion rates for differing soil types, vegetation, and slope lengths and gradients. Erosion for the base case was calculated for a sandy loam on a slope 100 m long at 18° (3H:1V) with no vegetation or support management. The base case estimated an annual erosion of 270 tonnes/hectare, which is considered severe in terms of crop soil loss. Single parameter values were then varied in the equation from the base case in order to illustrate the influence of each parameter on the final landform performance. Comparative graphs of the erosion estimates are shown in Figure 3 (b) through (e).

The analysis showed that erosion can be minimized by reducing slope lengths and gradients, using sandy covers, and ensuring thorough revegetation. The relationship between the amount of erosion and slope length is clear and almost linear – as slope length increases, so does erosion. As slope gradient decreases, erosion decreases; however, the effect becomes less pronounced at slope gradients shallower than 11° (5H:1V). This is important to note as regrading large, steep slopes to long, flat ones can be costly. From this analysis, it appears that short slopes covered with sand and densely vegetated with an angle of 11° or less will yield the least erosion from final landforms at Minto. This analysis shows that flatter slopes lead to reduced erosion.

In practical terms, slope lengths can be reduced by grading landforms such that multiple micro-catchments are constructed within a single landform. If absolutely necessary, sub-horizontal benches that reduce the cumulative energy of surface water can be constructed in such a way that standing water is avoided but that flow along the landform is still slowed. Revegetation also plays a large role in minimizing erosion as shown in Figure 3 (e), so landforms should be revegetated with appropriate mixes as soon as possible after landform construction has been completed.

4 Landform Design

4.1 Methodology

4.1.1 Landform Design Concepts

Landform design which adheres to the principles of fluvial geomorphology aims to emulate the characteristics of mature, natural landforms with fully developed and self-healing drainage systems. Such landforms are capable of adapting to geomorphological changes without accelerated erosion or unacceptable environmental impacts (Sawatsky and Beckstead 1995; Toy and Chuse 2005). Characteristics of landforms designed using these principles include:

- Slopes in equilibrium with local rainfall and soil conditions;
- Considerable variability in topographic relief;
- Well-defined watersheds with easily recognizable watercourses set in incised swales;
- Overland flow path lengths that do not violate thresholds that can be determined from local natural terrain;
- Watershed areas that do not exceed a threshold defined by the slope of their watercourses;
- Drainage systems patterned after natural streams in the surrounding area;
- Erosion rates comparable to those of the natural environment;
- Convex crests of increasing steepness transitioning to concave slope profiles that begin steep and become shallower along the flow path; and
- Drainage systems that are able to evolve and are “self-healing”.

Landforms designed using geomorphological principles have been shown to experience reduced erosion and improved hydrologic response to large storm events, as peak runoff rates and total runoff from these landforms have been shown to be lower than for traditionally engineered designs (Snyder 2013). Geomorphic landform designs have also been shown to have improved long term slope stability as there is often reduced migration of fine particles towards slope toes. This can improve slope stability by reducing the likelihood of slope toes becoming saturated (Russell 2012). The complex topography of geomorphic landforms has also been shown to increase flora diversity, which can lead to decreased erosion, improved slope stability, and better closure outcomes (Bugosh and Epp 2014). Figure 4 illustrates some of the landform design concepts described above.

4.1.2 Design Objectives

Closure landform design at the Minto Mine has the following objectives:

- Ensure the geotechnical stability of final landforms against surficial failures;
- Ensure the hydrotechnical stability of final landforms;

- Create conditions for the natural succession of vegetation on final landforms;
- Employ a combination of design slopes and vegetation to assist in maximizing erosional stability; and
- Develop criteria to assist with performance monitoring and maintenance of future reclaimed structures at the Minto Mine.

4.1.3 Landform Design Approach

In order to design landforms that meet the closure objectives, a methodology should be established that allows for investigation of natural landforms, site conditions, and possible techniques for incorporating natural landform features into final mine closure landforms. The following methodology is proposed:

- Observe natural landforms that are preferably mature and stable and note common features of these landforms, such as soil cover and moisture, slope length, profile, aspect and gradient, and vegetation cover;
- Look at site layouts and decide the course of action to create closure landforms that best emulate natural, stable landforms;
- Develop specific landform resloping designs that emulate natural landforms or the pre-mining landscape as much as practical;
- Evaluate options to create micro-landforms within larger landforms should it not be practical to emulate the natural landscape for large landforms; and
- Develop a progressive reclamation monitoring plan in order to monitor the performance of the designed landforms.

The above methodology was developed based on the principles of geomorphic landform design and was followed in the design of the SWD regrading and progressive reclamation plan. It should be considered in all future reclamation designs at the Minto site in order to be consistent with the principles of geomorphic landform design.

4.2 Results of Site-Specific Landform Analysis

4.2.1 Site Reconnaissance

Two SRK engineers travelled to the Minto Mine site for three days in late May 2014 to observe the natural geomorphological features in the general area of the mine as well as the immediate vicinity of the various waste dumps and other facilities. The current shape of the SWD, MWD, and DSTF were also observed and relevant features noted. Specifically, on built landforms, engineers looked for geotechnical stability indicators, erosional features, vegetation, slope angles and aspects, particle sizes and type, water conveyance structures, and areas with ponded water. In general, it was noted that:

- Most built landforms appeared geotechnically stable, even when apparently over steepened slopes are visible, at or exceeding theoretical angles of repose. There were a number of small surficial skin failures evident on some of the finer grained waste rock dump slopes;
- Erosion was very visible on most built landforms, and ranged from sheet erosion to considerable progressive rill and gully erosion. Most of the progressive rill and gulley erosion appeared to be associated with long continuous runoff surfaces, or areas where water was allowed to concentrate. Interestingly, some of the flatter regraded slopes appeared to show more demonstrated evidence of erosion;
- Physical composition of the different waste and overburden materials are highly variable, ranging from well-graded to poorly graded compositions with particle sizes ranging from boulders to silt. There was however no clear evidence of substantial self-armoring of erosion gulley's in any of these materials. Many of the finer grained materials do exhibit measurable evidence of erosional deposition at the slope toes; and
- Some areas are revegetating naturally, but by far the predominant reason for natural revegetation appears to be in areas where organic rich overburden soils are stockpiled; Areas where active revegetation has been done on organic poor overburden soils, vegetation succession appears to be poor.

In natural undisturbed landscapes in the vicinity of the site, engineers noted slope profiles and aspects, vegetation type, the presence or absence of standing water, erosional features, and channel profiles, cross-sections, and armouring material. These aspects of the surrounding natural landforms were observed and the information gathered will be used to inform the design of landforms that mimic the local natural geomorphic features. In general, it was noted during the site visit that natural landforms tended to have relatively shallow slopes with limited evidence of erosion. There was however clear evidence of well-developed gulley's parallel to most slopes suggesting that sheet flow is occurring with localized concentration. For the most part all slopes supported healthy vegetation, including many of the south southeast and south southwest facing slopes which are steeper than 3H:1V.

4.2.2 Landform Desktop Study

Catchment Areas

To complement the field observations, an investigation into the natural landforms in the general area of the Minto Mine was performed using GIS techniques. The investigation began with a review of the undisturbed catchment areas and the associated flow routing for each catchment area on site. It will be important to attempt to emulate these catchments in the reclamation designs for site landforms so as to ensure landforms are in equilibrium with landscape-wide flow patterns.

Groundwater flow in the Minto area is topographically driven and is generally towards Minto Creek, with recharge occurring at higher elevations and discharge occurring in valley bottoms. Reclaimed landforms at the Minto Mine should strive to maintain these flow directions in order to be hydrotechnically and erosionally stable. Catchment areas for the Minto Mine site are shown in Figure 5.

Slope Aspect

Slope directions, also known as slope aspects, were analyzed across the Minto Mine site and are pictured in Figure 6. In general, the mine lies in an area with east-west trending low mountain ranges that have significant variability in slope aspects across the site due to the curvilinear natural ridgelines that cause the slope aspects to vary along each slope.

The natural variability in slope aspect across the site is strongly correlated with vegetation type, which will be discussed further in sections below. The introduction of similar variability in slope aspect to reclaimed landforms at the Minto site wherever practical may lead to a wider variety of vegetation that is successfully established, and may ultimately lead to a more natural landscape over the long term post-closure.

Slope Gradient

From Figures 7 through 11, it can be seen that the majority of slopes in undisturbed areas are typically shallower than 18° (3H:1V), whereas slopes in mine-impacted areas are typically closer to 27° (2H:1V) for waste dumps or significantly steeper in the open pits. Figure 2 shows that areas close to natural ridgelines are often between 8° (7H:1V) and 14° (4H:1V), but away from the ridgelines the natural slopes become shallower than 6° (10H:1V). This is known as a concave slope profile, in which the slope is steeper at higher elevations and shallower at lower elevations, as shown in Figure 4. The analysis shows the significant variability in the natural slope angles.

Landform Patterns

Landform analysis found a correlation between elevation and surficial geology and a weaker (but still useful) correlation between slope aspect and vegetation type respectively.

The correlation between elevation and surficial geology is caused by the fact that certain soil types are stable only at certain slope angles, and as can be seen from Figure 2 and Figures 7 through 11, slope angles are also correlated with elevation in that slopes closer to crests and higher in elevation tend to be steeper than those farther from slope crests at lower elevations. At higher elevations and steeper slope angles, surficial geology tends to be either bedrock outcrop or a thin colluvial soil cover. At lower elevations and flatter slope angles, thicker sequences of glacial, periglacial, aeolian, and fluvial deposits are present, as pictured in Figure 12.

The correlation between slope aspect and dominant vegetation type is a function of the amount of sunlight experienced at different slope aspects, but is complicated by the recent fire history and subsequent vegetative succession. In general, southern aspects experience significantly more sunlight than northern aspects, which leads to decreased soil moisture contents, earlier snow melts, increased soil temperature and increased photosynthesis. These items combine to favour significantly different dominant species depending on the slope aspect, as can be seen in Figure 13. The present distribution of vegetation does not reflect the climax species mix at all locations due to the succession following various fires that have occurred at different times, and this likely is a factor in the weaker correlation between current vegetation and aspect.

5 Reclamation Land Units

The development of appropriate reclamation land units (RLUs) for the Minto Mine will facilitate achievement of the following outcomes:

- Geotechnical stability of reclaimed slopes;
- Minimal surface erosion by water and wind;
- Maintenance of acceptable long term water quality objectives, especially with respect to suspended solids; and
- Creation of conditions that will allow for re-colonization by native plant species, for basic ecological functions, and for use by local wildlife populations.

5.1 RLU Delineation

Delineation of reclamation land units is often based on end land use, initial and final surface configuration, and likely vegetation patterns (Bowman and Baker 1998). It is useful therefore to understand the land and vegetation patterns and existing biogeoclimatic zones defined within the given project area. Maps can be a valuable tool for achieving this. Biogeoclimatic zones are generally defined by superposition of the terrestrial ecozones and ecoregions, ecoclimatic regions, and the bioclimatic zones of a specific target area. The Minto Mine area is characterised as part of the Yukon Plateau ecoregion within the Boreal Cordillera ecozone (Figure 14), while from an ecoclimatic perspective, the mine area is part of the Northern Cordilleran High Boreal region (Figure 15).

Detailed biogeoclimatic zonation is not readily available for the Minto Mine area; however, extrapolation of biogeoclimatic zones onto the Minto site can be roughly performed based on the bioclimate zones determined for West Central Yukon (Figure 16) corroborated with the ecoclimatic description provided above.

Based on the above considerations, the vast majority of the Minto site falls within the Boreal High (BOH) biogeoclimatic zone, with some higher elevation areas possibly falling within the Subalpine (SUB) zone and some lower elevation areas falling within the Boreal Low (BOL) zone. In general, the BOH zone occurs at middle to upper elevations, is usually forested by black or white spruce, and is characterized by short, cool, and moist summers with long, cold winters. The SUB zone occurs at higher elevations on steep slopes and rocky highlands above the BOH and is sparsely forested or non-forested. The BOL zone occurs below the BOH zone at lower elevations along major river valleys and is usually forested by spruce and aspen with moderate understories. Vegetation is similar to the BOL zone but the warmer climate often results in much larger trees (McKenna *et al*. 2010).

5.1.1 End Land-use Designations

In the absence of published biogeoclimatic zones for the Minto site, reclamation land unit delineation was primarily based on End land-use designations. End land-use designations were defined by analyzing the native vegetation mapping data available for the Minto area as follows:

- Rocky Slope: Defined as slopes having little vegetation, coarse, thin soil veneers, and slopes steeper than 50% (27°, or 2H:1V). Roughly 6% of land in the Minto area falls into this category;
- Wetland: Defined as having flat slopes (<1%), thick vegetation, and standing water with organic soil. Less than 1% of land in the Minto area falls into this category;
- Forested: Defined as areas having primary vegetation types of Trembling Aspen, White Spruce, Black Spruce, Lodgepole Pine, or Alaskan Birch. Approximately 59% of land in the Minto area falls into this category; and
- Deciduous Shrubland: Defined as areas having primary vegetation types of Willow, Alder, or Scrub Birch. Approximately 35% of land in the Minto area falls into this category.

5.1.2 Slope Aspect

RLUs were then divided based on slope aspect category. Slope aspects can be categorized in a number of ways (France 2007; Gelbard and Harrison 2003); for the Minto site warm slopes were defined as having an aspect between 135^o and 270^o, cool slopes were defined as having aspects between 330^o and 90^o, and remaining aspects were defined as neutral. A schematic of this distribution is presented in Figure 17.

Flat slopes (defined as having a slope gradient less than 3°) were considered as a separate slope aspect category (Figure 18). Although in some cases aspect of these flat slopes may be directionally consistent with the cool slope, in practical terms these are warm slopes as direct solar radiation is received for most of the day.

5.1.3 Elevation, Slope Gradient, and Biogeoclimatic Zones

Four categories were defined based on the likely biogeoclimatic zones and the range in both slope gradient and elevation in the Minto area. These categories were formed based on the vegetation that the landscape in the Minto area will likely be able to support, and are as follows:

- BOL – Low elevations and flat slopes;
- BOH – Low to middle elevations and shallow to moderate slopes ranging from 1 to 25%;
- BOH – middle to high elevations and moderate to steep slopes ranging from 25-50%; and
- SUB – high elevations and steep slopes over 50%.

5.2 RLU Categories

Table 2 displays the RLUs for the Minto Mine site. It should be noted that these RLUs are conceptual only and have not yet been applied to specific areas of the site.

Table 2: Reclamation Land Units for the Minto Site

End Land-Use	**Biogeoclimatic Zone**	**BOL**	**BOH**	**BOH**	**SUB**
	Elevation	**Low**	**Low-Mid.**	**Mid.-High**	**High**
	Slope	**Flat (<1%)**	**Shallow-Mod. (1-25%)**	**Mod.-Steep (25-50%)**	**Steep (>50%)**
	Slope Aspect				
Forested	Cool and Neutral	-	FLm_{CN}	-	-
	Warm	-	FLm_{W}	FMh_{W}	-
Deciduous Shrubland	Cool and Neutral	-	SLm_{CN}	SMh_{CN}	-
	Warm	-	-	SMh_{W}	SH_{W}
Wetland	All	WL*	-	-	-
Rocky Slope	All	-	-	-	RH

* The first letter of each RLU denotes the end land-use category. The second and third (for some) letters denote the elevation category (i.e. L for low, Lm for low to middle). The subscript letters stand for slope aspect.

Figures 18 and 19 display the slope aspect and angle categories overlain by vegetation types that were used to define the RLUs for the Minto site. Figure 20 is a combination of slope aspect and angle in relation to vegetation. Mining-impacted areas where the slope differs significantly from the surrounding landscape, shown in black, will likely require significant resloping.

6 Discussion

6.1 Use of Site Specific Reclamation Land Units

In natural catchments, slope gradients develop over time as a function of prevailing substrate and hydrologic conditions. The type and amount of vegetation established on slopes depends heavily on the soil moisture availability of those slopes, which greatly depends on substrate, slope gradient, and slope aspect. Slopes on reclaimed landforms at the Minto Mine will likely experience less erosion and greater vegetation establishment if they are graded similarly to the surrounding natural slopes.

RLUs and landform design concepts have been defined for the Minto site based on site-specific features and the current mine plan. As progressive reclamation activities proceed according to the principles described in this document, it is expected that there will need to be opportunities for refinements to the design concepts, RLUs, and monitoring processes based on lessons learned during progressive reclamation and monitoring of performance indicators. As such, this should be considered a “live document”.

The RLUs defined in this document are conceptual and still need to be applied to specific landforms on the Minto site. It is important to work within the framework of the RLU categories from the beginning of progressive reclamation until final closure of specific landforms so that performance may be monitored accordingly and costs can be tracked to inform future closure planning. Progressive reclamation activities have already begun at the Southwest Waste Dump and RLUs are required there. The Main Waste Dump and the Dry Stack Tailings Facility will require RLU designations as soon as both facilities are complete or nearing completion, with initial progressive reclamation underway and final reclamation activities expected to begin in the near future.

The approach outlined in this report provides a basis for developing closure landform designs for each of the specific waste storage facilities at Minto Mine.

6.2 Reclamation Costing Considerations

While the RLUs were delineated based on various physical aspects of the site, they were also delineated in order to provide a framework for closure and reclamation costing. Specific land treatments can be developed for each RLU as part of the closure design detailing the amount of effort necessary to both reslope and revegetate mine-impacted landforms. Average costs may then be calculated to apply those treatments to each RLU, thus creating a unit cost basis for waste facilities and disturbed land reclamation.

For example, areas needing significant resloping will be more expensive to reclaim than those needing little or no resloping. As well, it is reasonable to assume that more effort will be necessary to revegetate cool and neutral forested slopes than warm slopes covered with shrub, so separate RLUs were defined accordingly. As progressive reclamation takes place within a specific RLU, actual completion costs can be recorded and projected for future reclamation activities.

6.3 Landform Monitoring

Monitoring should occur within the framework of the defined RLUs such that landform performance is measured for each RLU. Monitoring should begin while progressive reclamation takes place so that RLU assignments may be adjusted based on performance as reclamation proceeds.

Monitoring should include the following actions:

- Erosion monitoring – set up erosion monitoring stations on each RLU after reclamation activities have taken place to estimate the annual erosion from constructed closure landforms and compare to both degree of revegetation and to erosion estimated during design for performance indicators;
- Water quality monitoring – monitor water quality from closure landforms for each RLU, specifically for suspended solids along with any other pertinent quality indicators, depending on the landform; and
- Vegetation surveys – periodic surveys of vegetation establishment on each RLU to ensure reclamation goals with respect to vegetation type and density are being met.

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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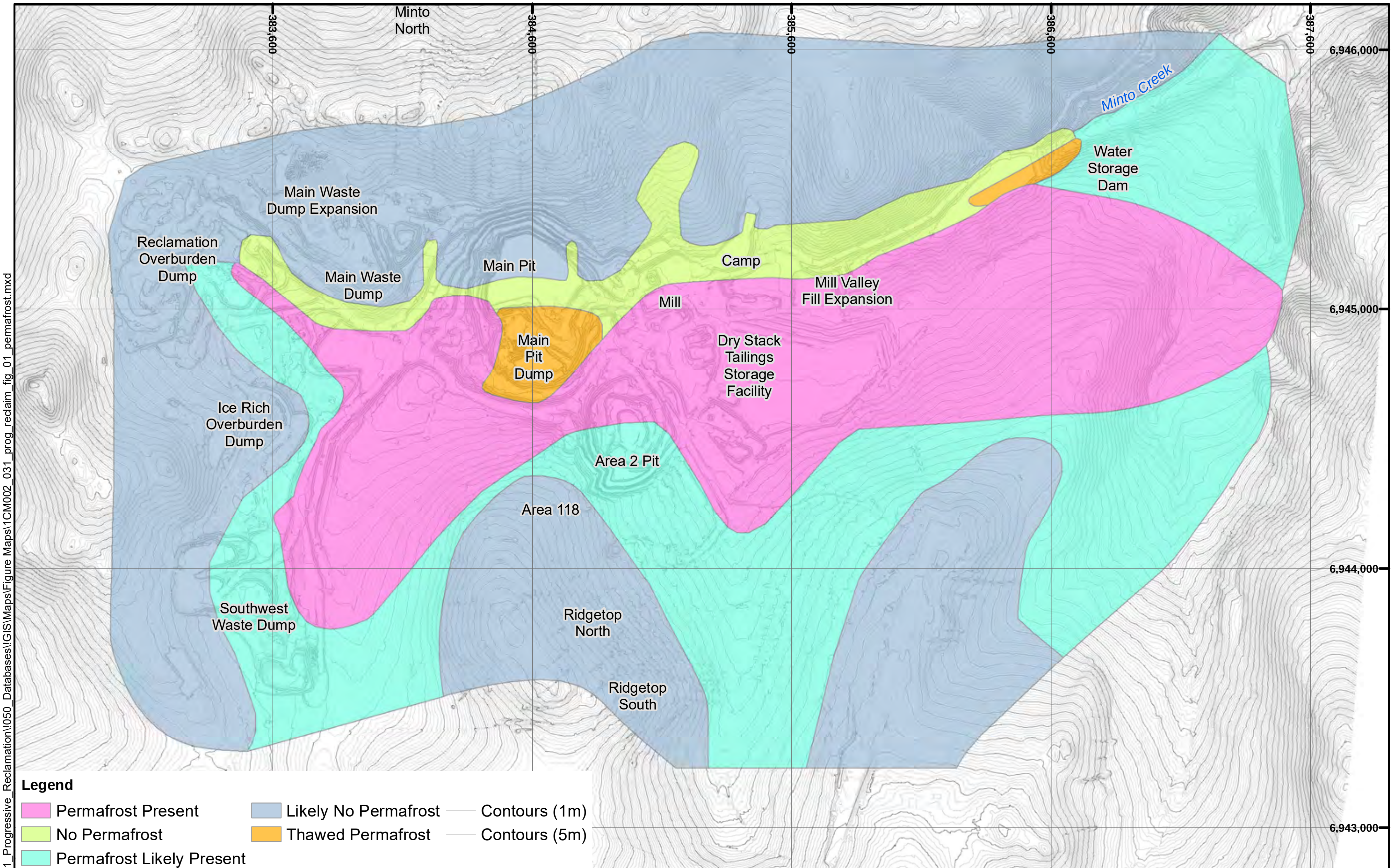
Figures



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MINTO MINE

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Minto Mine

Closure Landform Design and RLUs

Permafrost Extent Across Site

Date: April 2016 | Approved: EKH | Figure: 1

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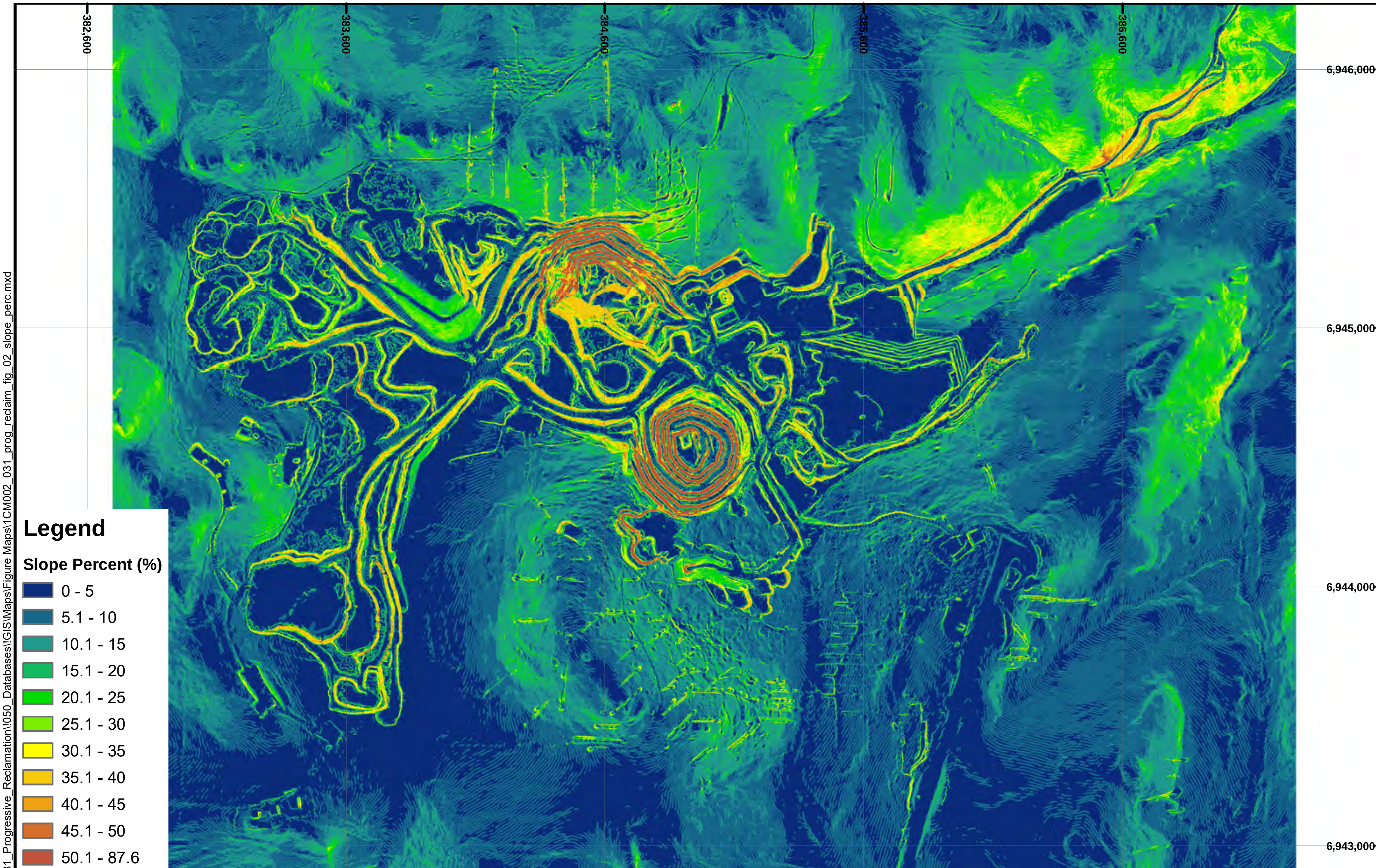

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Closure Landform Design and RLUs

Slope Gradients

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Minto Mine

Date: April 2016

Approved: EKH

Figure: 2

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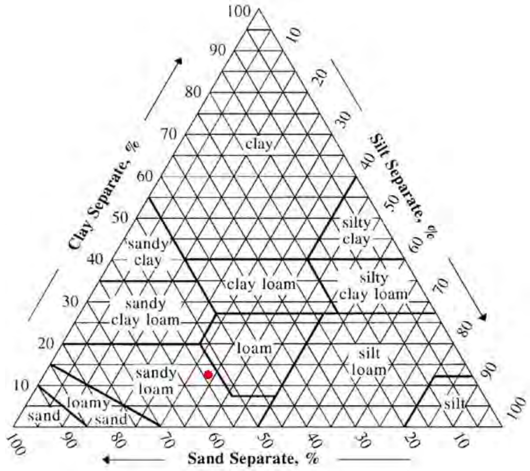
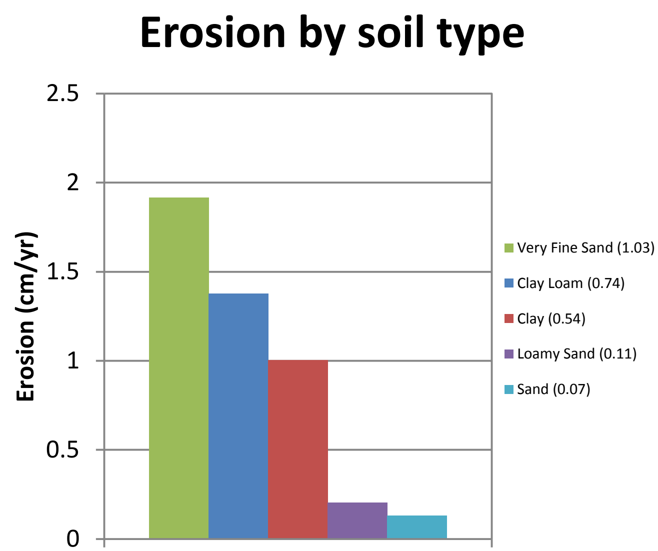


Average particle size distribution of soil in the ROD falls into the Sandy Loam category (USDA classification)

(a)



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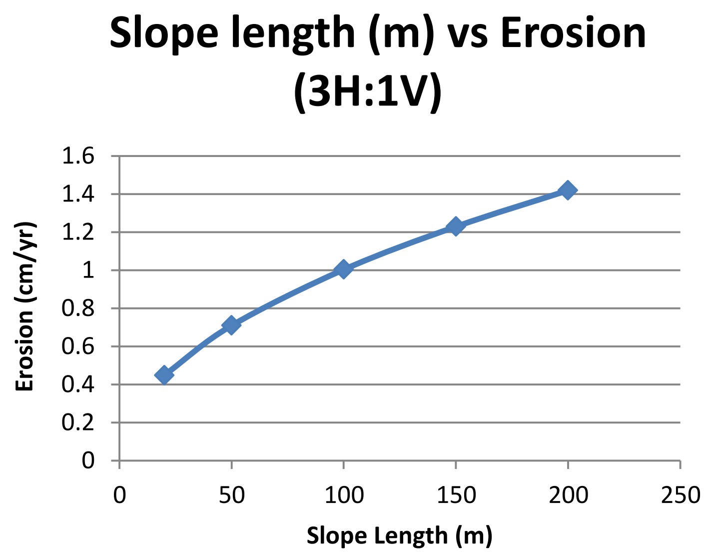
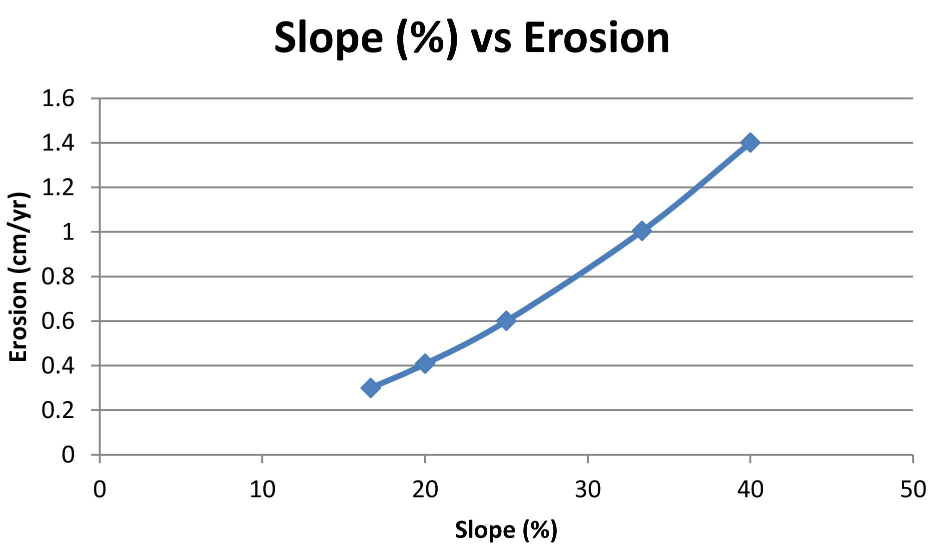


(c)



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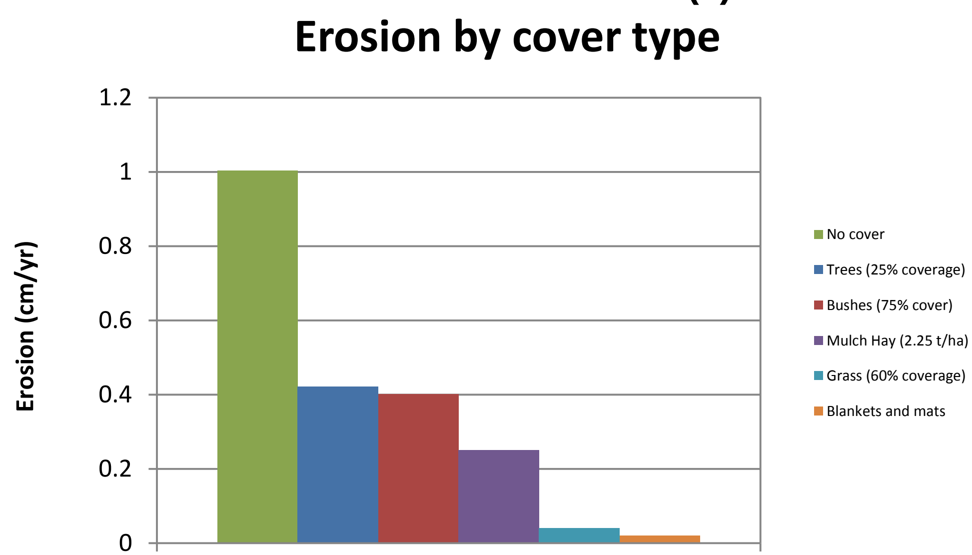

(e)

Note: Erosion modeling using USLE assumes uniform soil loss arising from sheet erosion – it does not address local gully erosion, and the results presented here are comparative rather than absolute. Density of soil was assumed to be 1.9 t/m^3 in calculations.

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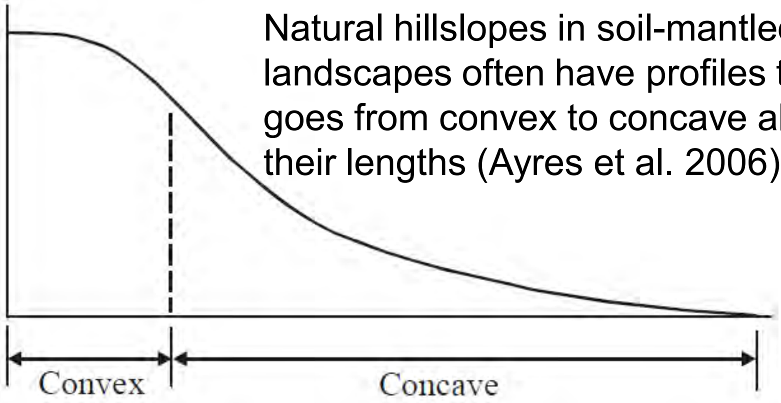
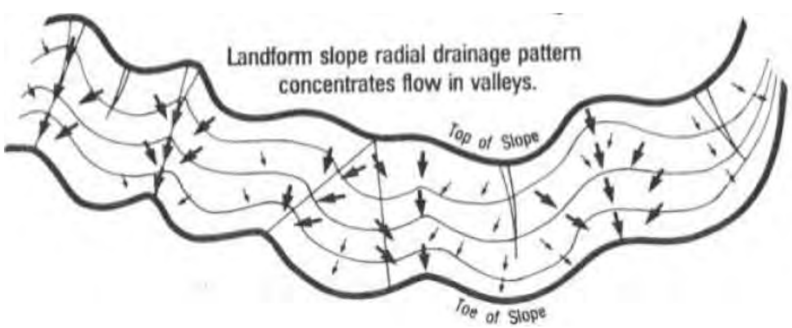
		Erosion Analysis
Job No: 1CM002.031 Filename: Fig03_ErosionAnalysis_rev02.pptx	Minto Mine	Date: April 2016 / Approved: EKH / Figure: **3**



Natural hillslopes in soil-mantled landscapes often have profiles that goes from convex to concave along their lengths (Ayres et al. 2006).



Landform-designed slopes have a radial drainage pattern that concentrate flow in valleys (Michael et al. 2010).

Landform-designed slopes are broken up into smaller drainage areas in order to limit the maximum overland flow path and resulting erosion (Schor and Gray 2013).

Sources

Ayres, B., Dobchuk, B., Christensen, D., O'Kane, M., Fawcett, M. (2006). Incorporation of Natural Slope Features into the Design of Final Landforms for Waste Rock Stockpiles. Paper presented at the 7th International Conference on Acid Rock Drainage (ICARD), March 26-30, St. Louis MO.

Michael, P., Superfesky, M., Uranowski, L. (2010). Challenges of Applying Geomorphic and Stream Reclamation Methodologies to Mountaintop Mining and Excess Spoil Fill Construction in Steep-Slope Topography in Central Appalachia. Paper presented at the Society for Mining, Metallurgy and Exploration (SME) Annual Meeting, Feb. 28 – Mar. 3, Phoenix, Arizona.

Schor, H. J., Gray, D. H. (2013). Landform/Geomorphic Grading for Sustainable Hillside Developments. Paper presented at Geo-Congress Conference 2013, March 3-6, San Diego, CA.

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Geomorphic Landform Design Concepts

Job No: 1CM002.031

Filename: Fig04_LandformDesignConcepts.pptx

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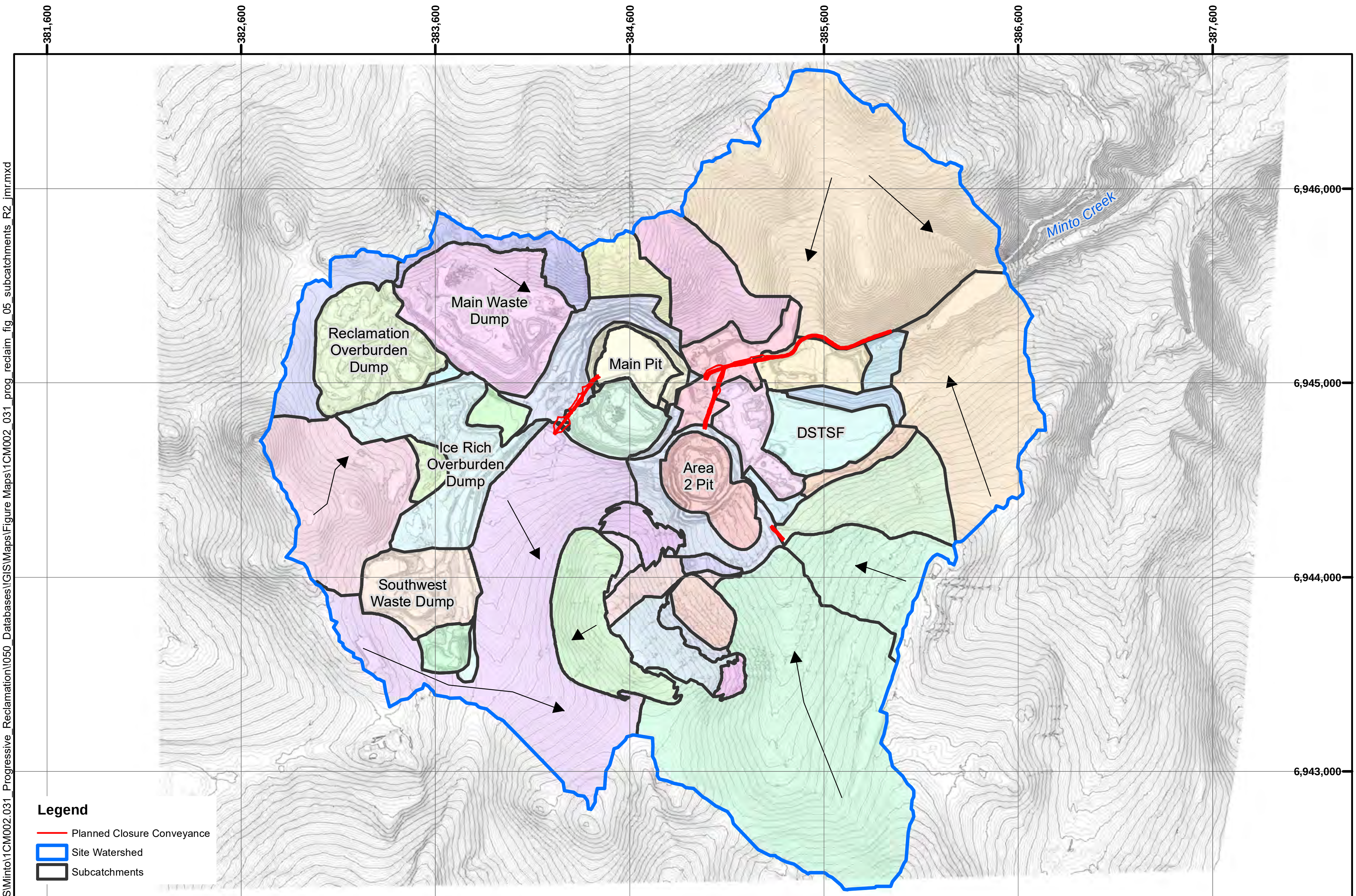
Date: April 2016 | Approved: EKH | Figure: 4



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Closure Landform Design and RLUs

Sub-Catchment Areas

Job No: 1CM002.031

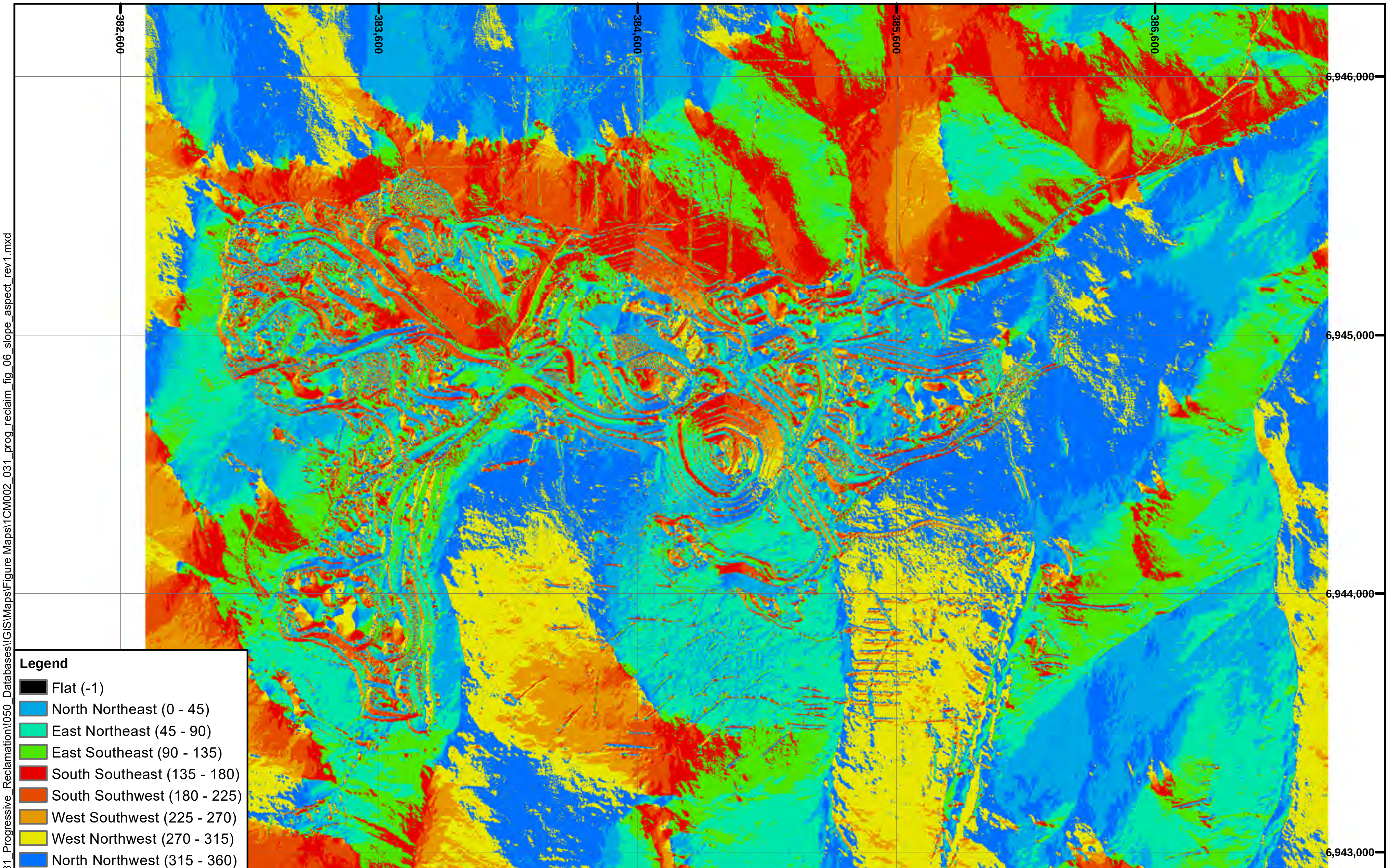
Filename: 1CM002_031_prog_reclaim_fig_05_subcatchments_R2_jmr

Minto Mine

Date: April 2016

Approved: EKH

Figure: 5



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Closure Landform Design and RLUs

Slope Aspect Distribution

Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_06_slope_aspect_rev1

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Date: April 2016

Approved: EKH

Figure: 6

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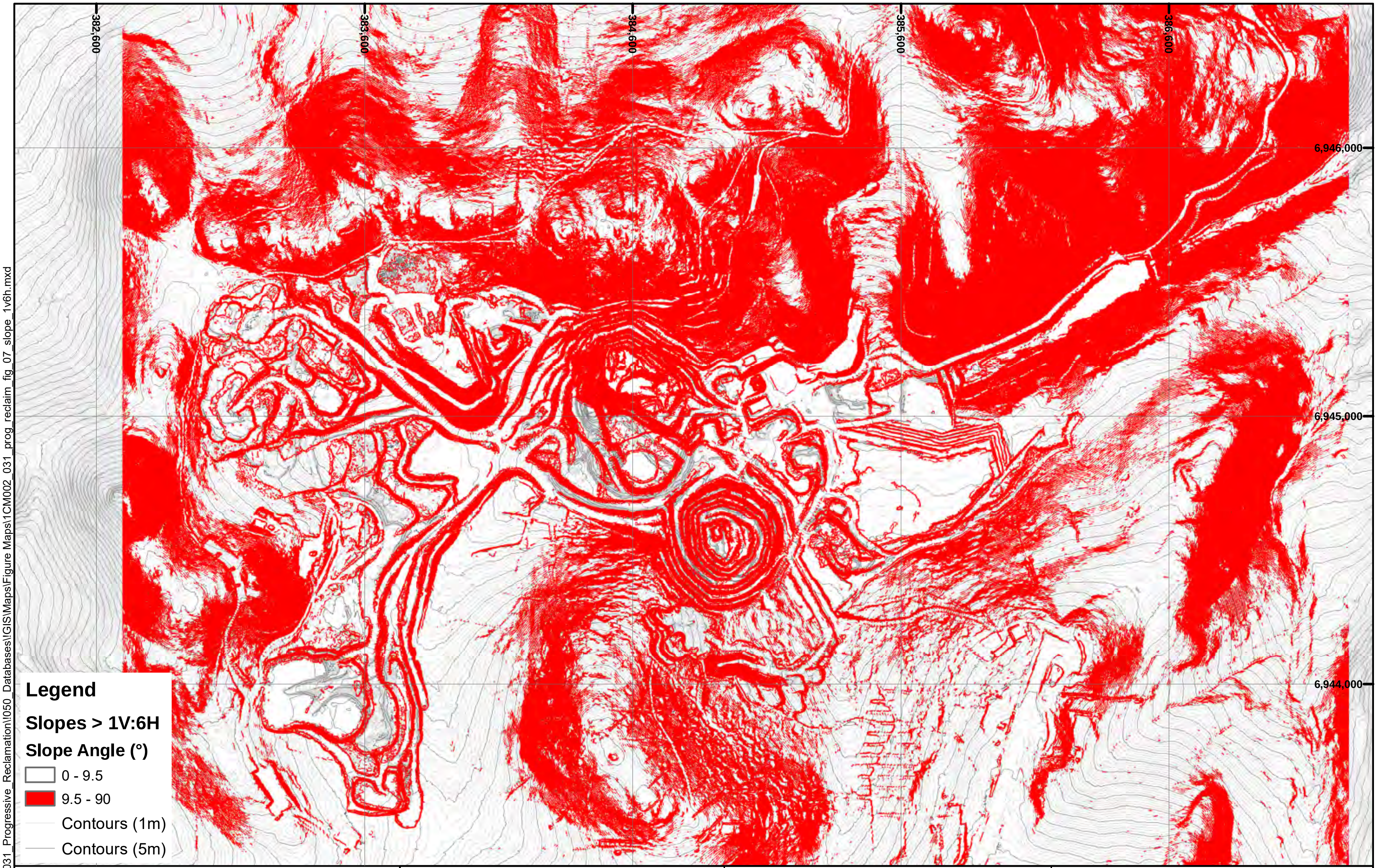

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Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_07_slope_1v6h

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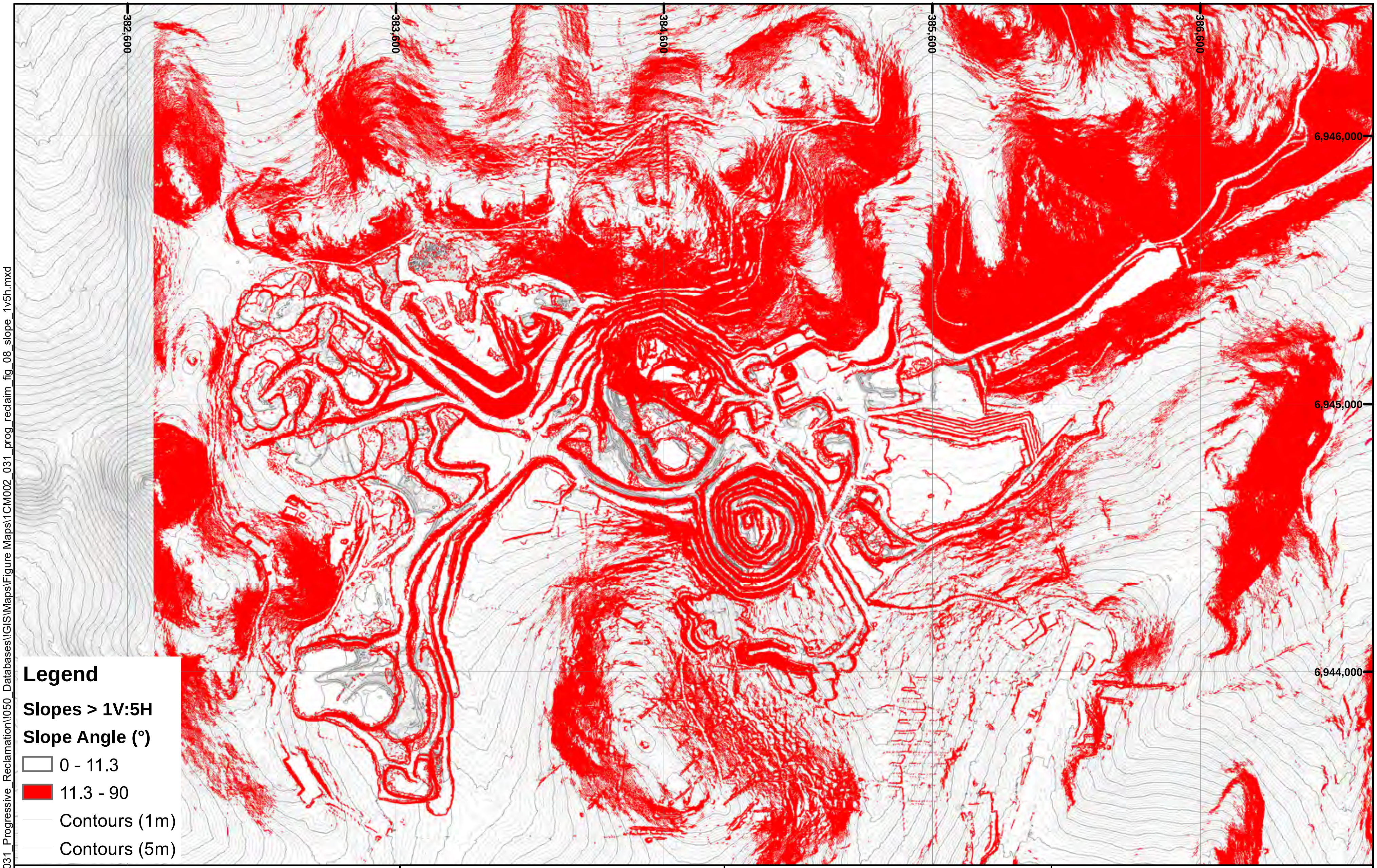
Closure Landform Design and RLUs

Distribution of Slopes Steeper than 6H:1V

Date:	Approved:	Figure:
April 2016	EKH	7



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Closure Landform Design and RLUs

Distribution of Slopes Steeper than 5H:1V

Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_08_slope_1v5h

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Date: April 2016

Approved: EKH

Figure: 8

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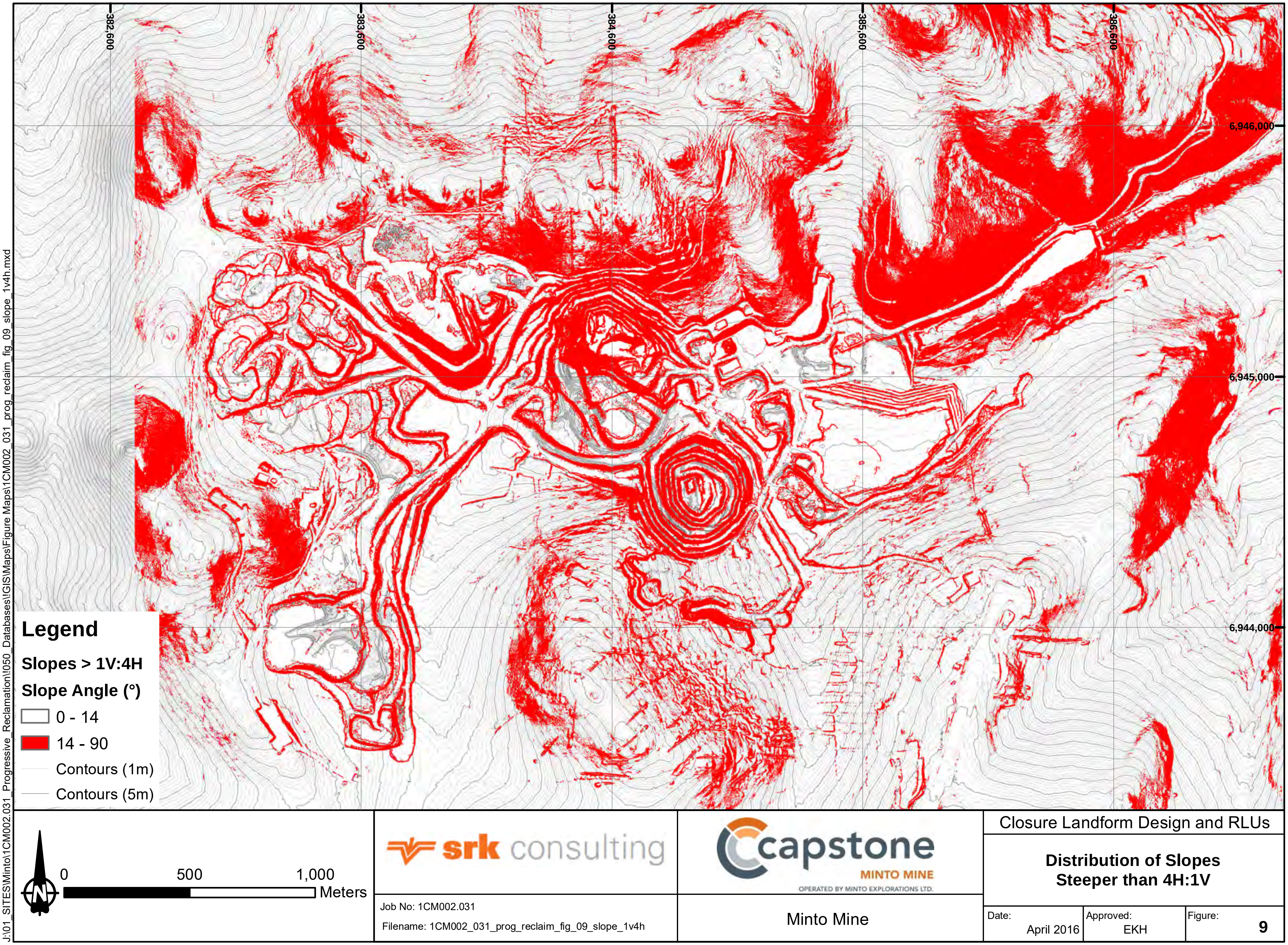

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Closure Landform Design and RLUs

Distribution of Slopes Steeper than 4H:1V

Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_09_slope_1v4h

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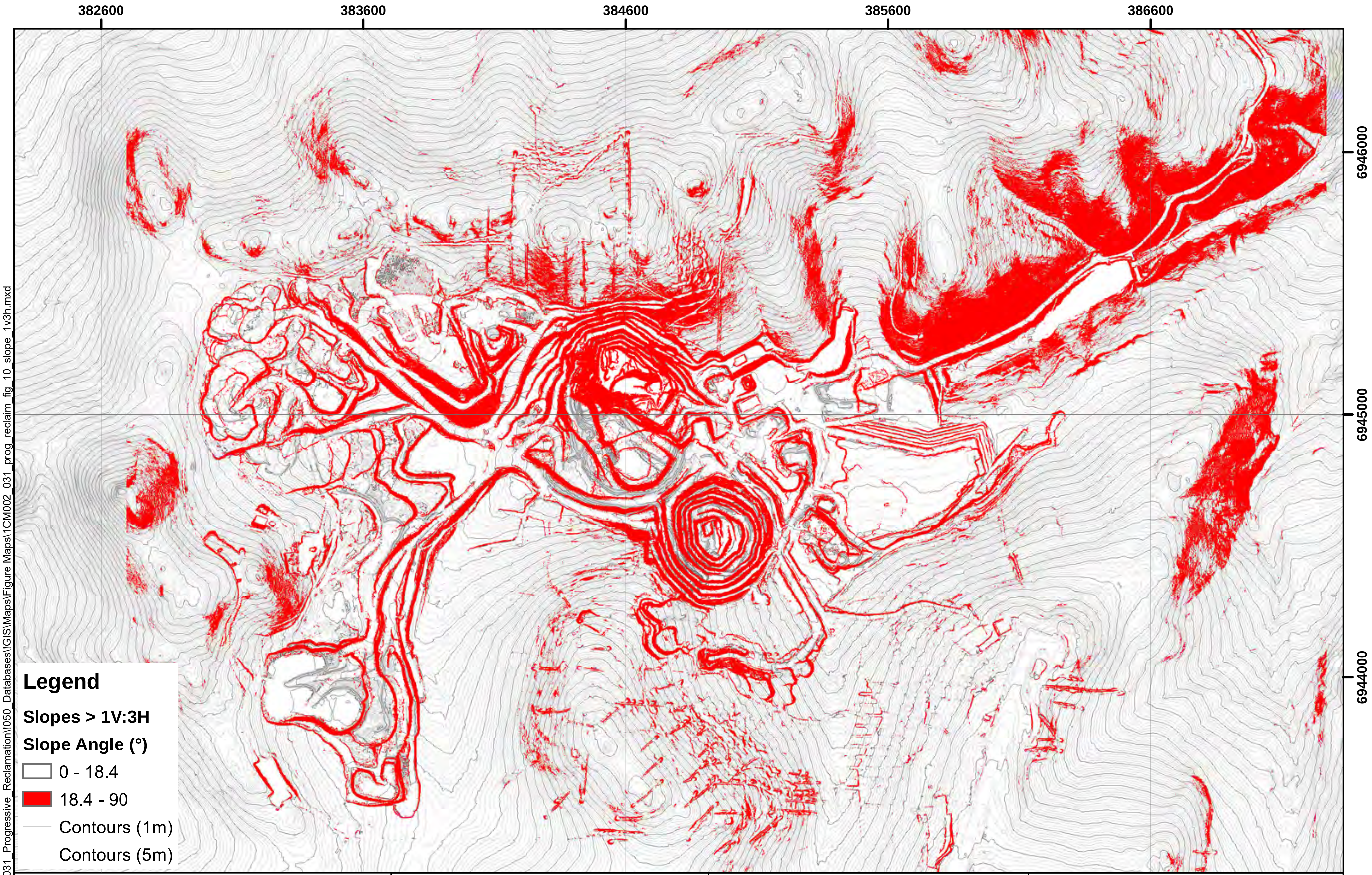
Date: April 2016

Approved: EKH

Figure: 9



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Closure Landform Design and RLUs

Distribution of Slopes Steeper than 3H:1V

Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_10_slope_1v3h

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Date: April 2016

Approved: EKH

Figure: 10

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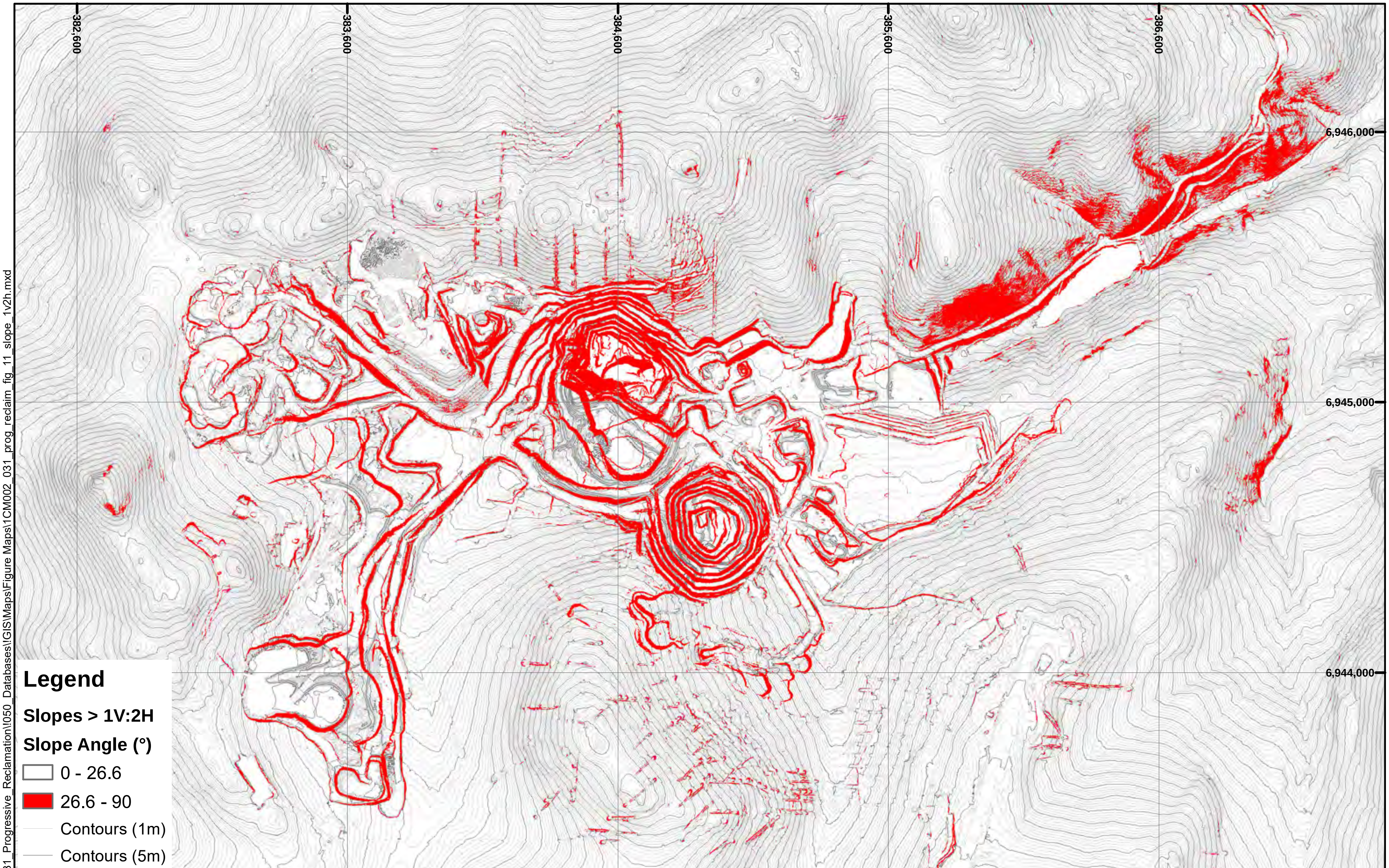

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Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_11_slope_1v2h

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Closure Landform Design and RLUs

Distribution of Slopes Steeper than 2H:1V

Date:	Approved:	Figure:
April 2016	EKH	11

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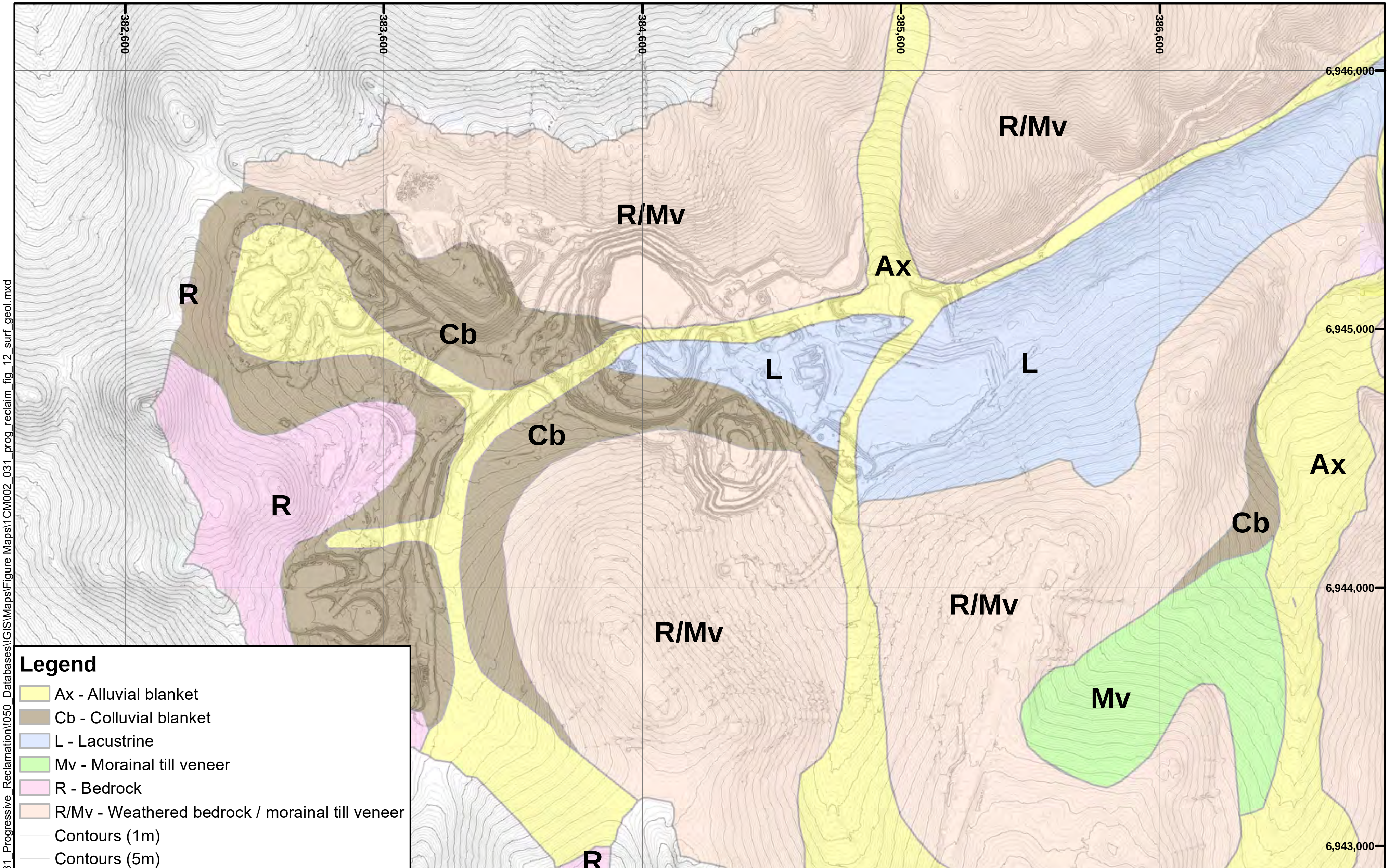

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Source: SRK Consulting (US) Inc. (2014). Surficial Geology Map - Minto Creek Watershed

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Closure Landform Design and RLUs

Surficial Geology Map

Job No: 1CM002.031
Filename: 1CM002_031_prog_reclaim_fig_12_surf_geol

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Date: April 2016
Approved: EKH
Figure: 12

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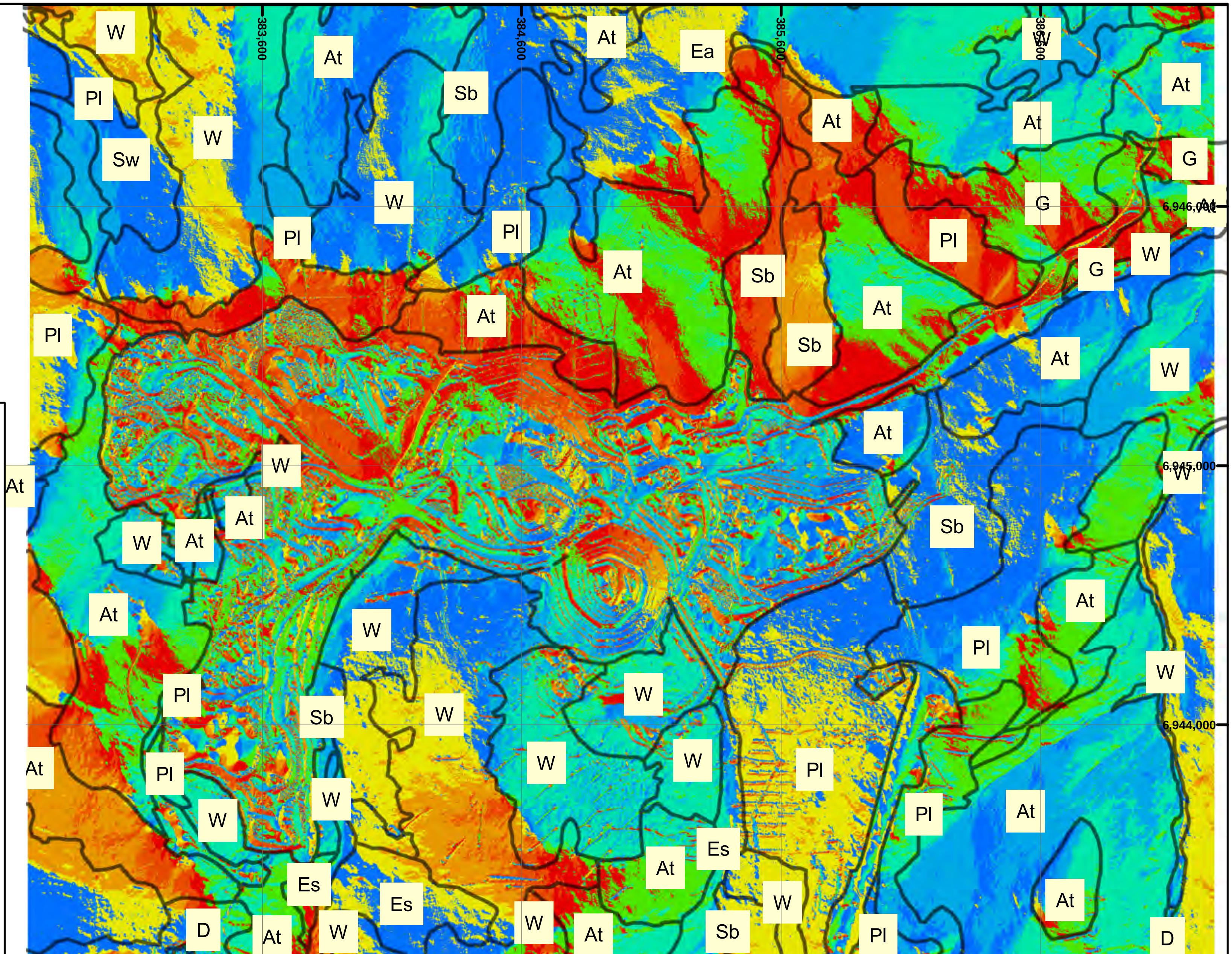

Legend

Leading Species

Slope Aspect

- Flat (-1)
- North Northeast (0 - 45)
- East Northeast (45 - 90)
- East Southeast (90 - 135)
- South Southeast (135 - 180)
- South Southwest (180 - 225)
- West Southwest (225 - 270)
- West Northwest (270 - 315)
- North Northwest (315 - 360)

Vegetation Species

At - Trembling Aspen
D - Alder
Ea - Alaskan Birch
Es - Scrub Birch
G - Graminoids
Pl - Lodgepole Pine
Sb - Black Spruce
Sw - White Spruce
W - Willow

0 500 1,000 Meters

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Job No: 1CM002.031
Filename: 1CM002_031_prog_reclaim_fig_13_slope_and_veg

Minto Mine

Closure Landform Design and RLUs

Slope Aspect and Vegetation Categories

Date:	Approved:	Figure:
April 2016	EKH	13

Source: Smith, C.A.S., Meikle, J.C., Roots, C.F. (2004). *Ecoregions of the Yukon Territory: Biophysical Properties of Yukon Landscapes*. Agriculture and Agri-Food Canada, PARC Technical Bulletin No. 04-01, Summerland, British Columbia, 313 p. Retrieved from: http://www.env.gov.yk.ca/animals-habitat/documents/ecoregions_of_yukon_reduced.pdf

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Closure Landform Design and RLUs

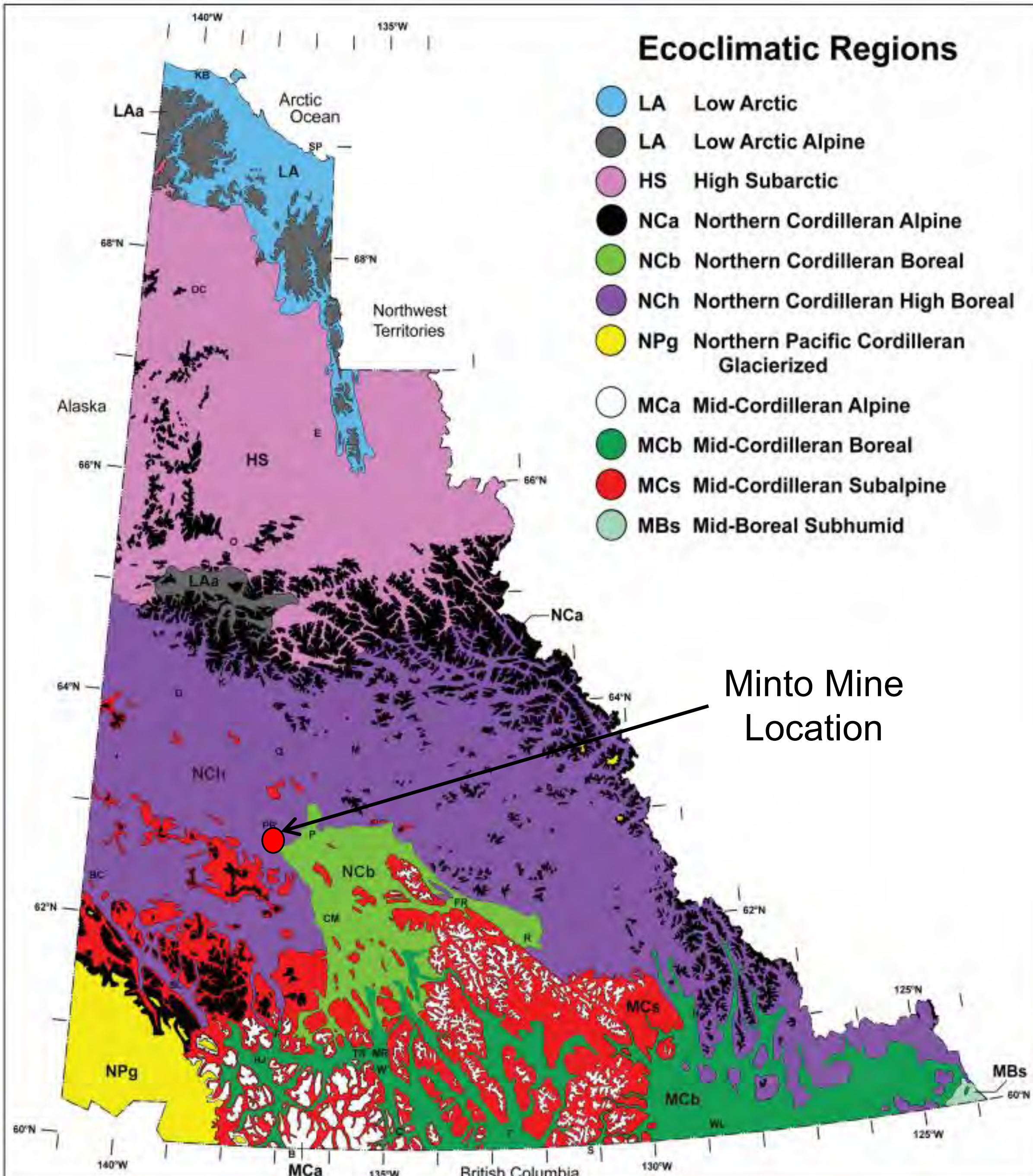
Terrestrial Ecozones of the Yukon

Job No: 1CM002.031

Filename: Fig14_TerrestrialEcozones_rev02.pptx

Minto Mine

Date:	Approved:	Figure:
April 2016	EKH	14



Letters other than ecoclimatic regions indicate the location of selected settlements and meteorological station locations: B – Blanchard River; BC – Beaver Creek; BL – Burwash Landing; C – Carcross; CM – Carmacks; D – Dawson City; E – Eagle Plains; F – Otter Falls; FR – Faro; H–Hour Lake; HJ – Haines Junction; K – Klondike; KB – Komakuk Beach; M – Mayo; MR – Mayo Road; O – Ogilvie River; OC – Old Crow; P – Pelly Crossing; PR – Pelly Ranch; Q – McQueston; R – Ross River; S – Swift River; SP – Shingle Point; T – Teslin; TR – Takhini Ranch; W – Whitehorse; and WL – Watson Lake.

Source: W.L. Strong (2013) Ecoclimatic Zonation of Yukon (Canada) and Ecoclinal Variation in Vegetation

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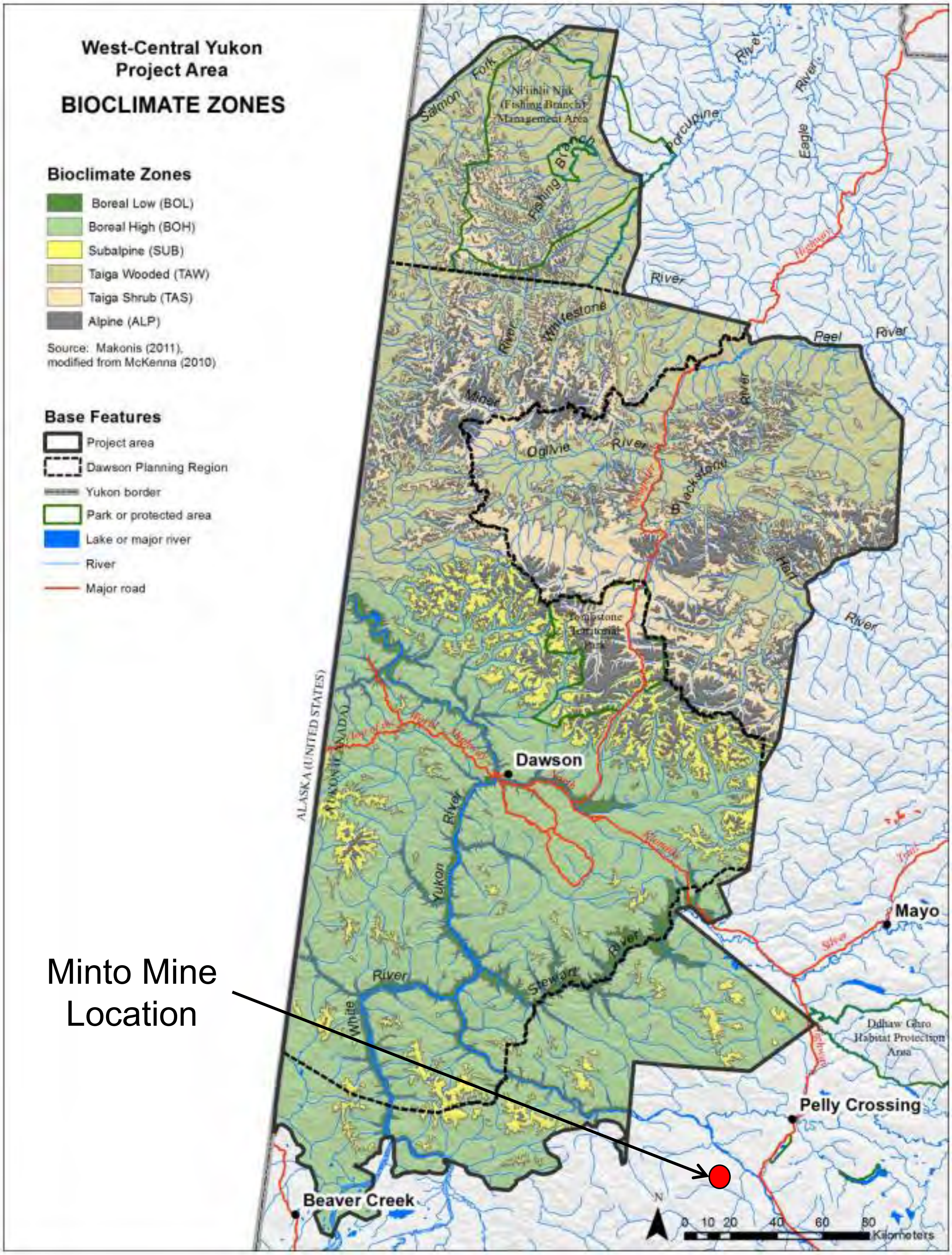
Job No: 1CM002.031 Filename: Fig15_EcoclimaticZones_rev02.pptx	Minto Mine	Date: April 2016	Approved: EKH	Figure: 15



Source: Makonis Consulting Ltd. (2012) Regional Ecosystems of West-Central Yukon

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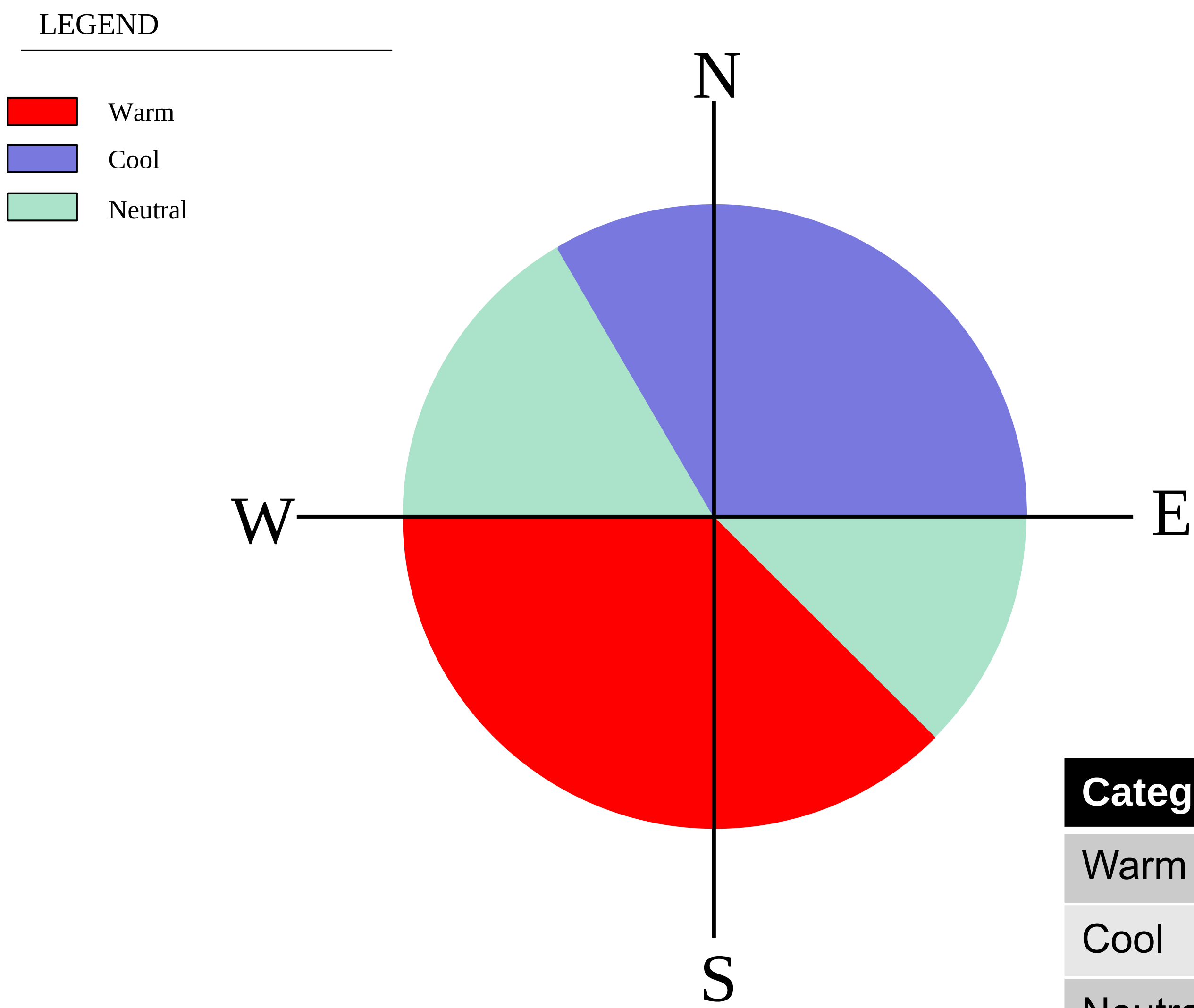
Job No: 1CM002.031 Filename: Fig16_BiogeoclimaticZones_rev02.pptx	Minto Mine	Date: April 2016	Approved: EKH	Figure: **16**



Category	Azimuth Range (º)
Warm	135 – 270
Cool	330 – 90
Neutral	90 – 135, 270 – 330

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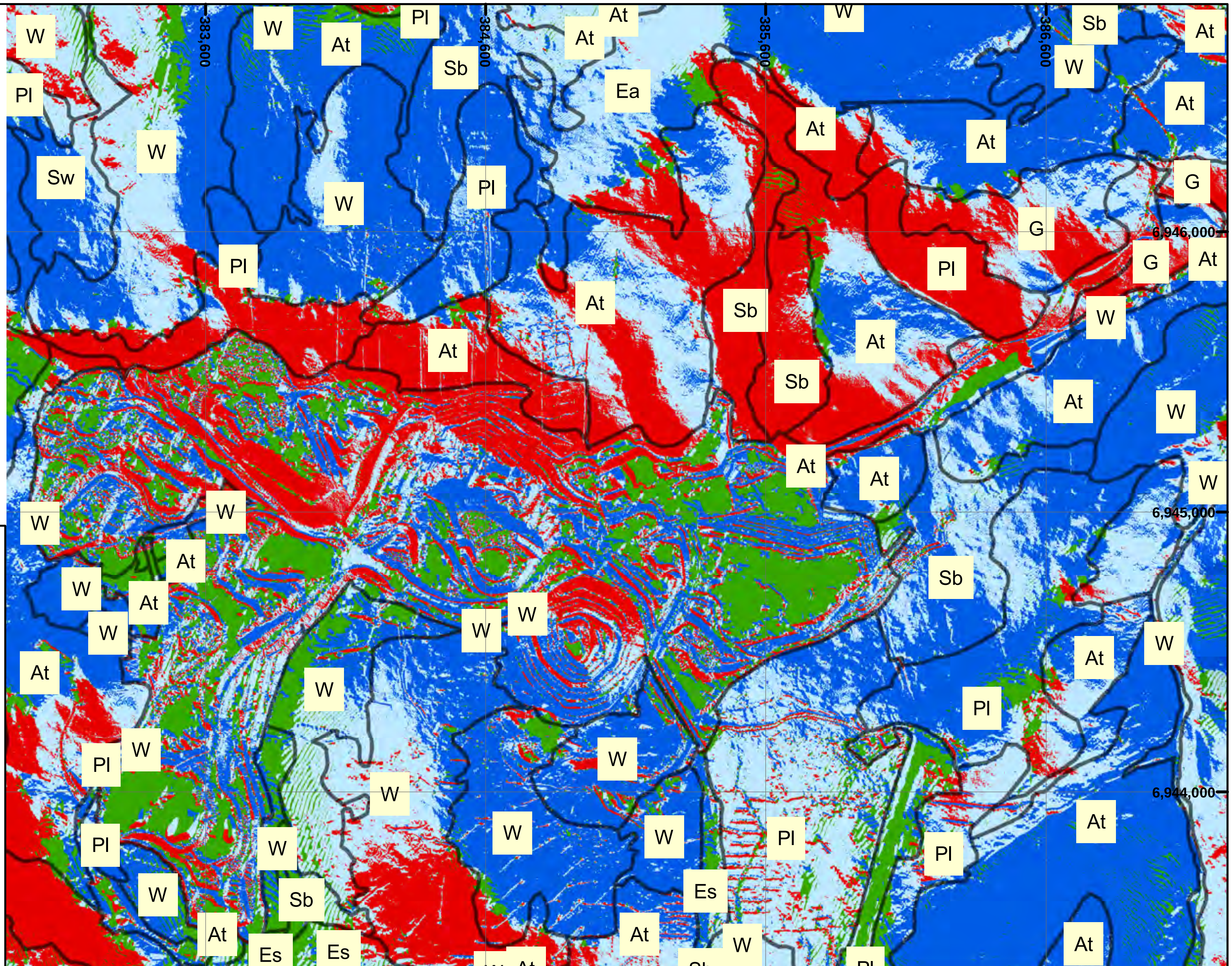
Closure Landform Design and RLUs

Slope Aspect Category Limits Schematic

Job No: 1CM002.031
Filename: Fig17_SlopeAspectSchematic.pptx

Minto Mine

Date: April 2016 | Approved: IM | Figure: **17**



Legend

Primary Species-Vegetation

Aspect

- Flat - All Aspects
- Sloped - Warm
- Sloped - Cool
- Sloped - Neutral

Vegetation Species

At - Trembling Aspen
D - Alder
Ea - Alaskan Birch
Es - Scrub Birch
G - Graminoids
Pl - Lodgepole Pine
Sb - Black Spruce
Sw - White Spruce
W - Willow

N

0 500 1,000 Meters

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Closure Landform Design and RLUs

Vegetation Categories and Slope Aspect

Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_18a_slope_angle_veg

Minto Mine

Date:	Approved:	Figure:
April 2016	EKH	18

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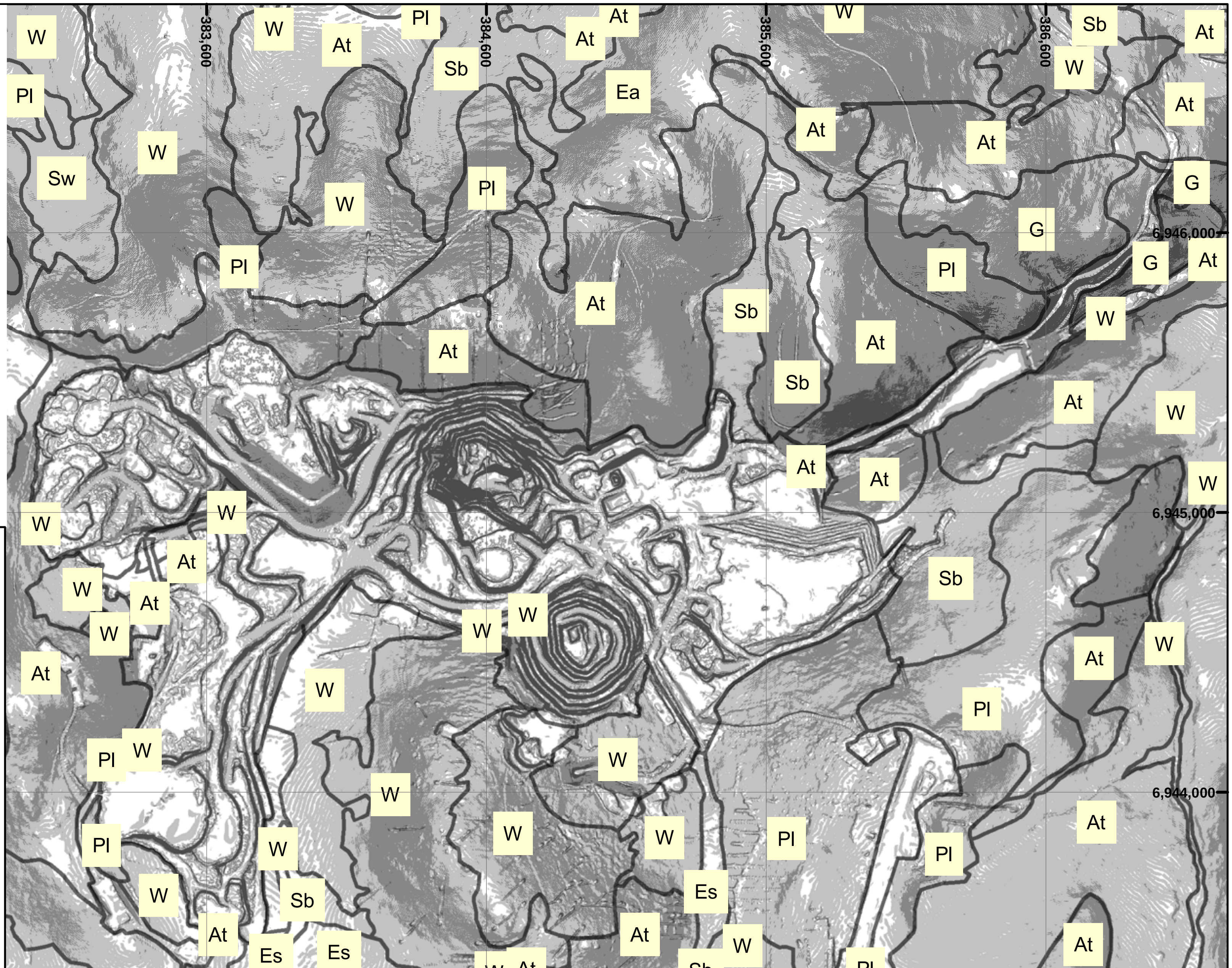

Legend

Primary Species-Vegetation

Slope (degree)

- Flat (0° to 3°)
- 6H : 1V (3° to 10°)
- 4H : 1V (10° to 14°)
- 2H : 1V (14° to 27°)

Vegetation Species

At - Trembling Aspen
D - Alder
Ea - Alaskan Birch
Es - Scrub Birch
G - Graminoids
Pl - Lodgepole Pine
Sb - Black Spruce
Sw - White Spruce
W - Willow

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Closure Landform Design and RLUs

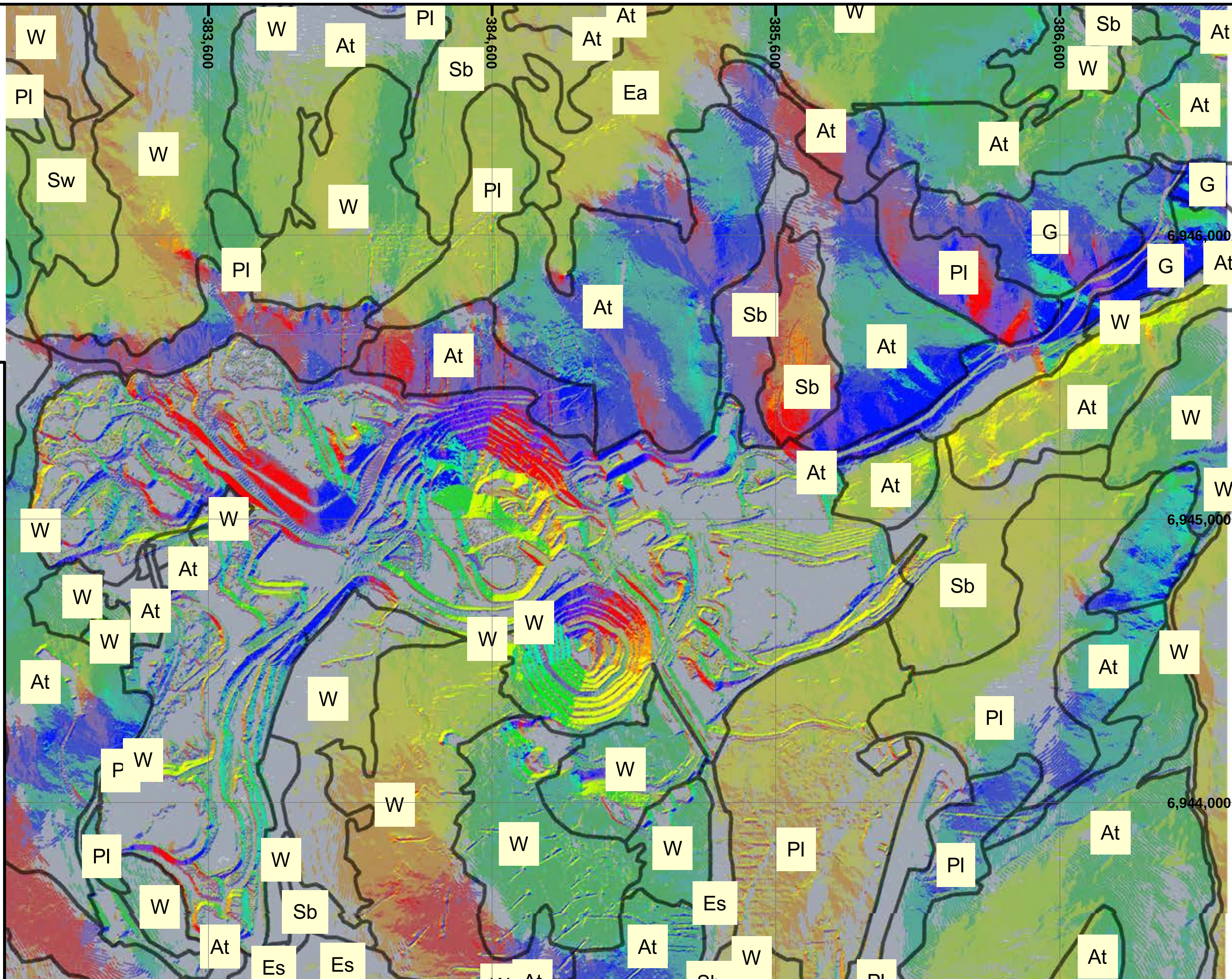
Vegetation Categories and Slope Angle Categories

Job No: 1CM002.031

Filename: 1CM002_031_prog_reclaim_fig_18b_slope_angle_veg

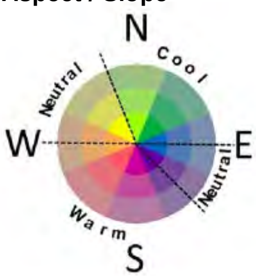
Minto Mine

Date:	Approved:	Figure:
April 2016	EKH	19



Legend

Aspect / Slope



Color Map
Inner Ring - Steep Slopes
Middle Ring - Moderate Slopes
Outer Ring - Shallow Slopes

Vegetation Species
At - Trembling Aspen
D - Alder
Ea - Alaskan Birch
Es - Scrub Birch
G - Graminoids
Pl - Lodgepole Pine
Sb - Black Spruce
Sw - White Spruce
W - Willow

0 500 1,000 Meters

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Site-Wide RLU Designation

Slope Aspect, Angle, and Vegetation Categories

Job No: 1CM002.031
Filename: 1CM002_031_prog_reclaim_fig_19_slope_angle_veg

Minto Mine

Date: Nov 2015 | Approved: JBK | Figure: **20**

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Appendix F
Background Water Quality of Lower Minto Creek for Application in the Derivation of Post-Closure Water Quality Objectives

Appendix G1
Minto Mine Reclamation and Closure Plan – Preliminary Design Report for Treatment Wetland

Appendix G2
Closure Water Conveyance System Design 2018 Update Report, Minto Mine

Appendix H
Minto Site Characterization Plan 2018-01

Appendix I
Water and Load Balance Model Report 2018

Appendix J1
Minto Mine - Operations Adaptive Management Plan 2020-01

Appendix J2
Closure Adaptive Management Plan 2020-01

Appendix K
Minto Mine Closure Cost Estimates – RCP Revision 2020-01