Minto Mine
Reclamation Research Plan

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Minto Mine
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Contents

1 Reclamation Research Update

An important component of the reclamation planning process at the Minto Mine is ongoing reclamation research with the objective of developing the methods required to implement a successful reclamation program. This document provides an update to the previous reclamation research plan and reflects our evolving understanding of the site conditions as well as recent and anticipated modifications to the Minto mine layout. This update is also intended to meet the requirement of Water Use Licence QZ96-006, s.98, which requires:

> *On or before November 30, 2012, the Licensee shall submit to the Board a detailed Reclamation Research Plan detailing reclamation research and studies currently being carried out, or that are proposed to be carried out, to support reclamation plan development at the site. This plan should include, but not necessarily be limited to, the following:*
>
> *a) overall plan for proposed reclamation research and studies;*
> *b) goals, rationale, deliverables, timing, linkages to other studies and research; and*
> *c) how results of the research will be used to support the DRP.*

It is important to recognize that the mine plan is evolving as ore reserves have continued to expand and as we gain improved understanding of the mine waste characteristics and the physical conditions on the ground.

The design of the reclamation research program is intimately connected with the Reclamation and Closure Plan (RCP), formerly DRP, which is itself an evolving document. The process of updating the RCP is currently underway, with the next formal update scheduled for submission June 1, 2013. The updated RCP will incorporate a formal alternatives assessment of the full range of potential reclamation technologies and will propose an optimal integration of the most promising technologies.

This document reflects current understanding and will evolve over the coming months as the RCP update process advances.

1.1 Context for the Reclamation Research Update

The reclamation research plan described herein is designed to identify and evaluate reclamation and remediation technologies that are considered both promising and feasible for incorporation into the evolving mine RCP.

A significant amount of work has already gone into developing reclamation concepts and strategies in order to address the known and anticipated environmental challenges at the Minto Mine site.

It is recognized that site conditions and the anticipated mine closure configuration have changed since the previous reclamation research program was developed. Additionally, it is recognized that some of the earlier closure concepts may not be feasible as originally proposed, resulting in new environmental challenges and a requirement to evaluate additional reclamation technologies to address the changed site conditions.

Some of the more significant changes to the site conditions and mine plan are described below along with the implications for closure planning:

i. Pit-wall instability in Area 1 Pit: This has resulted in the need for additional buttressing to stabilize the pit wall and has reduced originally planned subaqueous storage capacity available for high grade waste rock at closure. Consequently, it is no longer feasible to store all high grade waste rock subaqueously in the Area 1 Pit as originally proposed.

ii. Observed geotechnical instability in the Dry Stack Tailings (DST): Documented movement of the tailings pile has resulted in the need to backfill the valley downgradient of the DST fill in order to buttress the tailings stack and mitigate the risk of further movement. Consequently, surface and groundwater flow has been altered in the area of the DST – creating both challenges and opportunities for future site wide water management and treatment options.

iii. Observed geotechnical instability in the Southwest Waste Rock Dump (SWD): Documented instability within the foundation of the SWD has resulted in a need to both modify the footprint of the dump and limit the dump height. It will be important to take stability concerns into consideration when developing the final closure configuration and surface water management strategies.

iv. Potential pockets of PAG waste rock within the Area 2 pit development: Ongoing geochemical monitoring of the waste rock dumps has indicated that there may be a higher percentage of PAG waste rock than previously anticipated. Consequently, it will be necessary to re-evaluate closure cover concepts and mine waste management practices in areas of potentially problematic waste rock. Additionally, the updated WR geochemical properties have implications for seepage water quality and the types of potential passive and semi-passive treatment options that may be appropriate downgradient of the WR dumps.

v. Minto Explorations Limited (Minto) continues to identify additional reserves: The new reserves will translate to both increased areas of disturbance and increased total volume of mine waste to be managed. Modifications to the mine plan have broad implications for site wide water management, and will impact the feasibility of such passive treatment technologies as constructed wetlands, energy dissipation features and sediment control ponds.

1.2 Reclamation Goals

The overall goal of closure at the Minto site is to leave the area as a self-sustaining ecosystem, ensuring that land use after closure is compatible with the surrounding lands, and that the site vegetation returns to a state as near as possible to that in existence prior to mining activities. Operations phase material characterization programs and the application of passive mitigation treatments such as engineered covers to reduce metal loadings from mine infrastructure components are the primary means by which Minto proposes to achieve this goal. The reclamation technologies adopted will reflect the reclamation goals of Minto which are presented in the Decommissioning and Reclamation Plan (Version 3.2 dated June 2011).

1.3 Reclamation Problem Statement (Site Challenges)

The current reclamation research program is designed to identify the most promising reclamation technologies based on our current understanding of site conditions. This reclamation research program will continue to evolve in concert with both the upcoming Closure Options Evaluation process and updating of the RCP.

The environmental and reclamation challenges at the Minto Mine are typical of large mining operations and include:

- Large areas of disturbance which must be recontoured and reclaimed/revegetated;
- Erosion of soils and the associated sediment loads to surface water; and
- The potential of metal leaching from mine waste and areas of disturbance

Additionally, the site is located in an area which experiences extreme seasonal temperature and climate fluctuations combined with an intense spring freshet. This reality must be fully accounted for in any reclamation strategy.

Preliminary water quality modelling for water seeping from the Minto waste rock piles and dry stack tailings storage facility suggests that, under worst case waste load predictions, infiltration reducing covers over these facilities will be required as part of a strategy to ensure site wide water quality objectives can be met. The predictive modelling has indicated that, in isolation, covers that reduce infiltration by 80% of mean annual precipitation will not achieve the required load reductions to meet water quality objectives. Covers of that performance quality will have to be implemented in conjunction with some form of passive treatment system, and even then elements such as cadmium and selenium could be problematic. This suggests that high quality infiltration reducing covers will likely be required at Minto as Yukon regulations do not support use of perpetual water treatment (active treatment approach) as a closure strategy.

Given the above, it is recognized that the RCP will need to incorporate a wide variety of reclamation strategies and technologies, all working together synergistically in order to address the known and anticipated environmental challenges and meet the reclamation goals identified in Section 1.2.

2 Process for Identifying Optimal Reclamation Technologies

As discussed previously, the RCP is currently being updated and will incorporate a Closure Options Evaluation which will consider the full range of potential closure scenarios and associated reclamation technologies and strategies. Significant research has already been completed on the revegetation aspect of reclamation and considerable study has been given to determining the required cover performance. This work is ongoing and we will continue to build on the existing studies and field trials going forward.

It is recognized that optimal revegetation and cover design will not, on their own, enable the site to meet water quality discharge criteria and the stated reclamation goals without the incorporation of additional passive treatment systems and technologies. To date, passive treatment technologies have typically been discussed at the conceptual level. Going forward, options for passive treatment will be evaluated in a much more rigorous manner and studies will be initiated to both provide proof of concept and enable the design of robust, self-sustaining systems.

It is proposed that the primary tool used in the evaluation of passive treatment technologies will be the Interstate Technology Research Council (ITRC) Mining Waste Treatment Technology Selection Guidance Document (http://www.itrcweb.org/miningwaste-guidance/). The ITRC is an organization that brings together environmental experts and stakeholders from the public and private sectors with a two-fold mandate to develop technical knowledge and streamline the regulation of new environmental technologies.

The (ITRC) Mining Waste Treatment Technology Selection Guidance Document provides an efficient process for identifying appropriate treatment technologies through use of a formal decision matrix and detailed technical backup in the form of technical guidance documents that facilitate more detailed evaluation, design and implementation of the identified preferred treatment technologies. This process is particularly well suited for incorporation in the upcoming alternative assessment associated with the updating of the RCP.

The technology review process applies to all impacted media (air, water, soil and vegetation). The decision tree is presented in a series of questions with recommended options depending on the media impacted and the time frame required for action. The decision tree is a useful tool to streamline the decision process for selection of closure options at the Minto Mine. ITRC also maintains an extensive library of guidance documents which will facilitate advancing the process from technology selection through to detailed design and implementation. Minto and its consultants will also make use of applicable northern climate guidance documents in the decision process such as those produced by Mine Environmental Neutral Drainage (MEND).

3 Updated Reclamation Research Program for Minto Mine Closure

Reclamation research to date has primarily focused on revegetation and cover requirements, with passive and semi-passive treatment technologies typically being discussed only at a high level.

This section provides an update on the reclamation research completed to date and presents the plans for continuing work that is already underway. This section also provides comment regarding how Minto intends to evaluate new reclamation technologies – including passive and semi-passive treatment technologies, in-pit water treatment and possible passivation of the mine waste - and develop new research and field scale projects to provide proof of concept and derive detailed design parameters.

3.1 Revegetation Trials

Documentation of natural revegetation successes is ongoing during current reclamation research activities as documented in the annual reclamation reports. Information developed on site will be supplemented with information obtained from other mine reclamation programs in the Yukon and other jurisdictions. Considerable research has been carried out into the reclamation and revegetation of disturbed lands in the Yukon, including operating and abandoned mines, and mineral exploration sites. Much of this information is in the public domain and is well presented in the guidance document Mine Reclamation in Northwest Territories and Yukon (INAC, 1992.)

Revegetation research work began at the Minto Mine in 2007 and it marked the beginning of a multi-year reclamation research program that will provide critical site-specific information to guide successful decommissioning and reclamation of the site. The program continued through 2008 – 2010 and identified a preferred native seed mixture and fertilizer application rate for revegetation activities at the site. Minto is currently in the process of scaling up those results and incorporating other variables into a larger scale revegetation/reclamation trial as part of progressive reclamation of the Main Waste Dump (MWD).

For the MWD cover trials, two variables will be assessed: plots representing major types of overburden found on site will be created to assess their suitability as cover material, and amendments such as fertilizer and organic material will be compared to simply seeding the overburden, to ascertain if these amendments improve seeding success. In the near future the cover trial will support vegetation and become a living test plot. It will not only provide information to customize site-specific reclamation methods, but it will also stabilize inactive slopes, reduce the amount of reclamation taking place at end of mine life, and improve aesthetics of the site.

The information obtained here will assess the feasibility of ongoing reclamation project success at Minto by observing:

- slope workability for equipment, operators and workers
- ease of accessing previously stockpiled material and challenges working with this material
- seeding methods used and their transferability to other dump surfaces or other reclamation projects
- erosion control methods

Ongoing data collection in the future growing seasons will provide additional information:

- assessing success of seed mix on large scale plots
- determining if different types of overburden on site can support vegetation
- gauging benefit of using amendments to overburden (organic matter and/or fertilizers)

Minto's Annual Reclamation Research Report, 2011, includes previous work executed on the MWD waste rock recontouring and overburden placement that took place in 2011. That work and the work completed in 2012 is summarized in Figures 1, 2 and 3.

Photo 1 - April 2011, original surface of MWD. Note 4 distinct waste rock benches that will be recontoured into 2 long slopes.

Figure 2 - September 2011, Recontouring of waste rock stopped shortly after this photograph due to snow cover. Overburden placement continued until October when stockpiles froze.

Figure 3 - July 2012, final MWD surface after waste rock recontouring and overburden placement

3.1.1 Overburden plots

Plot placement

To support further investigation into suitable cover materials required under Minto's June 2011 Decommissioning and Reclamation Plan (DRP), materials were recovered from the site's Reclamation Overburden Dump (ROD), characterized, and placed in distinct plots (Figure 4). The naming convention for the plots reflects their position on the MWD. There are two benched areas, identified as "Upper and Lower". West facing slopes and east facing slopes are also pointed out in the convention. Figure 5 below indicates the naming convention for the plots, along with their areas.

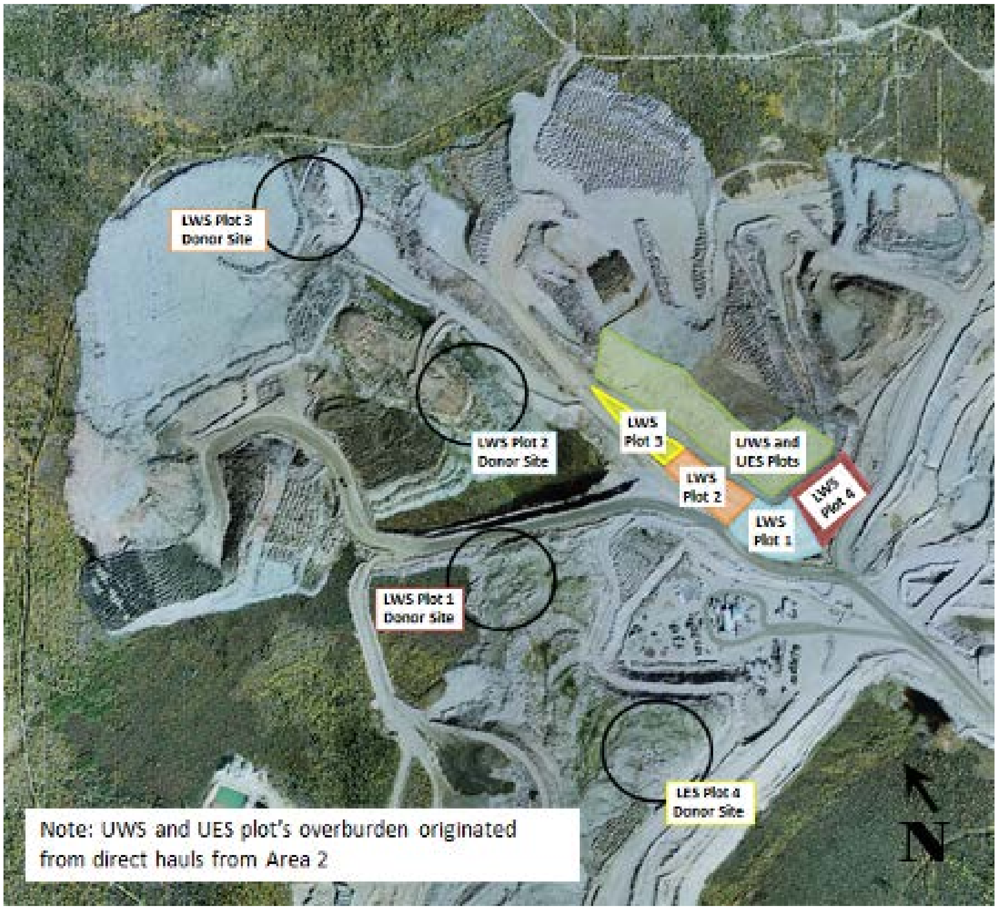

Figure 4 – Origin of overburden material from ROD placed in distinct plots on the MWD re-contoured rock surface.

			Area (m2)	Area (ha)	Depth of OVB cover (mm)	Total volume of material placed (m3)
Plot Name	Upper West Slope (UWS) and Upper East Slope (UES)	**UWS and UES Plots**	17229	1.72	1000	17229
	Lower West Slope (LWS)	**LWS Plot 1**	10309	1.03	1000	10309
		LWS Plot 2	6237	0.62	500	3118
		LWS Plot 3	6219	0.62	1000	6219
	Lower East Slope (LES)	**LES Plot 4**	3970	0.40	1000	3970

Figure 5 – Naming convention, areas, volumes and depths of each overburden plot

Plot size was chosen to balance the minimum area required to initiate enough diverse treatments to analyze different scenarios, and field fitting the plots for the most efficient use of space. Each overburden plot was chosen to represent materials available from the overburden stripping that occurred in Area 1 and 2 pits. As mentioned in Figure 4, the upper slope plots were capped with material directly excavated and hauled from Area 2 pit development indiscreetly, without much segregation. A selection method occurred for the lower slope's plots within the ROD area. Sites were chosen to represent a wide range of materials on site (gravelly and sandy overburden, to loam-textured, to overburden containing high clay content pockets). Stockpiles and pads of materials were surveyed for material types using field cues (hand texturing, colour comparison, visual estimation of coarse to fine material composition) (Figures 6 to 15).

Figure 6 – LWS Plot 1 donor site

Figure 7 – LWS Plot 1 close up of material. Dark brown, heavy, silty overburden with streaks of clay throughout. Organic-like odour and lenses of ice visible.

Figure 8 – LWS Plot 2 donor site, note deep grey colour.

Figure 9 – LWS Plot 2 material being placed. It is heavy, medium grey silty clay material with less frozen ice lenses than the other sites.

Figure 10 – LWS Plot 3 donor site, note light grey coloured material.

Figure 11 –LWS Plot 3 tracked and placed material on the MWD. Light grey silty material, gravel stratified throughout. Large chunks of ice excavated throughout profile**.**

Figure 12 – LES Plot 4, donor site. Very sandy overburden with gravel throughout.

Figure 13 – LES Plot 4, close up of material.

Figure 14 – UES and UWS plots excavation site, Area 2 pit. Photo taken March 2012. Note cut face of overburden to the right side of the photo.

Figure 15 – Example of material excavated and placed from Area 2. It was placed and spread in the fall of 2011. This ice rich, loamy material defrosted and thawed in the fall and spring; this and snow melt contributed to evidence of rilling and other erosion.

Overburden characterization

To characterize materials, composite samples were collected from each type of overburden represented within the 5 plot areas. Gradation, hydrometer, Atterberg limits, moisture content, permeability testing with porosity, soil water characteristic curve and specific gravity are being measured by EBA Engineering at their Whitehorse office.

3.1.2 Seeding and Amendments

Plot placement and preparation

The seeding surface was prepared by lightly grading the surface with the blade of a CAT D-6 dozer. On slopes that had overburden placed from 2011, this grading increased moisture on the surface and disturbed the hard surface created by heavy snow pack over the winter of 2011/2012 (Figure 16). The dozer tracks running up and down the plot's surface, perpendicular to the slope, was carried out to produces microbenches for revegetation. These microbenches enable increased capture of moisture, seeds and fertilizer pellets in depressions (Figure 17).

Figure 16 – Plot surface after grading

Figure 17 – Close up of microbenches

Plots were designed to field fit two amendment applications along with one control area within each section of overburden plots. Their layout is depicted in Figure 12. Plots were laid out initially by field fit and their final location was determined by Trimble GPS survey equipment to calculate area.

The amendment options were seed applied at a rate of 34 kg/ha or 340 kg/ha, or seed and fertilizer applied at a rate of 34 kg/ha and 125 kg/ha, respectively, or seed and fertilizer applied at a rate of 340 kg/ha and 1250 kg/ha, respectively (Refer to Figure 18 and 19).

Figure 18 - Diagram of MWD recontoured surface indicating locations of plots

			Area (m2)	Area (ha)	Seeding Rate (kg/ha)	Seed Applied (kg)	Fertilizer Rate (kg/ha)	Fertilizer Applied (kg)	Organic Material Applied (m^2)	Date Seeded
Plot Name	Upper West Slope (UWS)	**UWS Plot C**	1200	0.12	-	-	-	-	-	-
		UWS Plot Or	1200	0.12	34	4.1	-	-	12	3-Jul-12
		UWS Plot A	2037	0.20	34	6.8	-	-	-	3-Jul-12
		UWS Plot B	3516	0.35	340	119	-	-	-	28-Jul-12
		UWS Plot D	5256	0.53	34	17.9	-	-	-	30-Jun-12 and 24-Aug-12
	Upper East Slope (UES)	**UES Plot A**	1260	0.13	340	44.2	1250	162.5	-	22-Jul-12
		UES Plot B	1140	0.11	340	37.4	-	-	-	23-Jul-12
		UES Plot C	1620	0.16	-	-	-	-	-	-
	Lower West Slope (LWS)	**LWS Plot 3-C**	6219	0.62	-	-	-	-	-	-
		LWS Plot 3-B	3470	0.35	34	11.8	-	-	-	22-Aug-12
		LWS Plot 3-A	910	0.09	34	3.1	125	11.4	-	22-Aug-12
		LWS Plot 2-C	1030	0.10	-	-	-	-	-	-
		LWS Plot 2-B	4540	0.45	37.3	12.9	-	-	-	23-Aug-12
		LWS Plot 2-A	1330	0.13	37.3	3.4	125	16.6	-	23-Aug-12
		LWS Plot 1-C	1200	0.12	-	-	-	-	-	-
		LWS Plot 1-B	6600	0.66	34	22.4	-	-	-	24-Aug-12
		LWS Plot 1-A	2500	0.25	34	8.5	125	31.25	-	23-Aug-12
	Lower East Slope (LES)	**LES Plot 4-A**	948	0.09	340	30.6	1250	22.5	-	26-Jun-12
		LES Plot 4-B	1069	0.11	340	37.4	-	-	-	27-Jun-12
		LES Plot 4-C	1953	0.20	-	-	-	-	-	-
		Total Area of Seeded Plots =	52968	5.30	**Total Seed Used =**	297.4	**Total Fertilizer Used =**	185		

Figure 19 - Legend of plot amendments corresponding with

Seeding Methods and Supplies

A dry land seed mix optimized by Access Consulting in previous Reclamation Research Reports (2007, 2008, 2009, 2010) was ordered from Pickseed Canada in Sherwood Park, AB (Figure 20 and 21). Seed certificates were reviewed upon delivery.

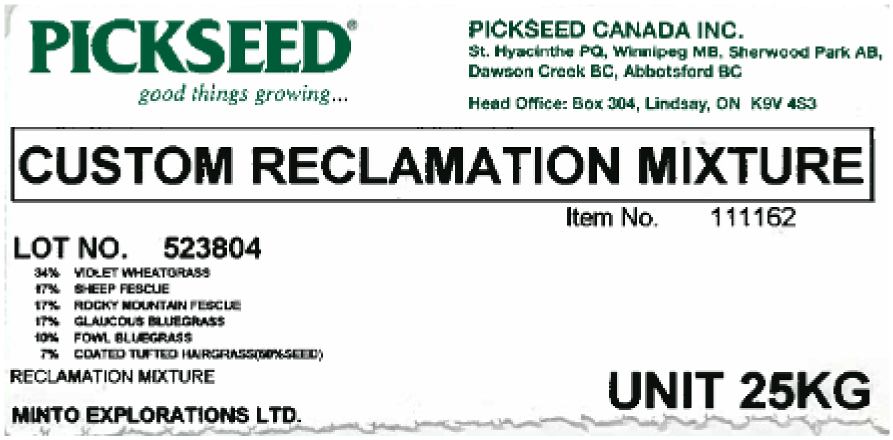

Figure 20 – Seed tag from seed order received May 2012.

Figure 21 – Close up of seed composition, mixture of diverse seed sizes

20-22-12 fertilizer was ordered from a local supplier, Arctic Alpine Seeds in Whitehorse, Yukon.

Plots were hand seeded usingbucket design tree planter. Seed was weighed out into each bag using pre-weighed containers, up to an accuracy of 0.1 kg for seed and 1 kg for fertilizer. The sections were divided into smaller sections for seeding, depending on how many seeders were available to help, to accommodate a maximum of ~13kg per seeder. Rebar stakes were placed around the perimeter of the area to be seeded. One seeder calculated the prescribed seed and fertilizer application, based on seeding and fertilizer rate, and divided the seed evenly among seeders. Then, seeders walked perpendicularly along the slope, evenly spaced apart, taking care to throw seed as evenly as possible (See Figure 22 and 23).

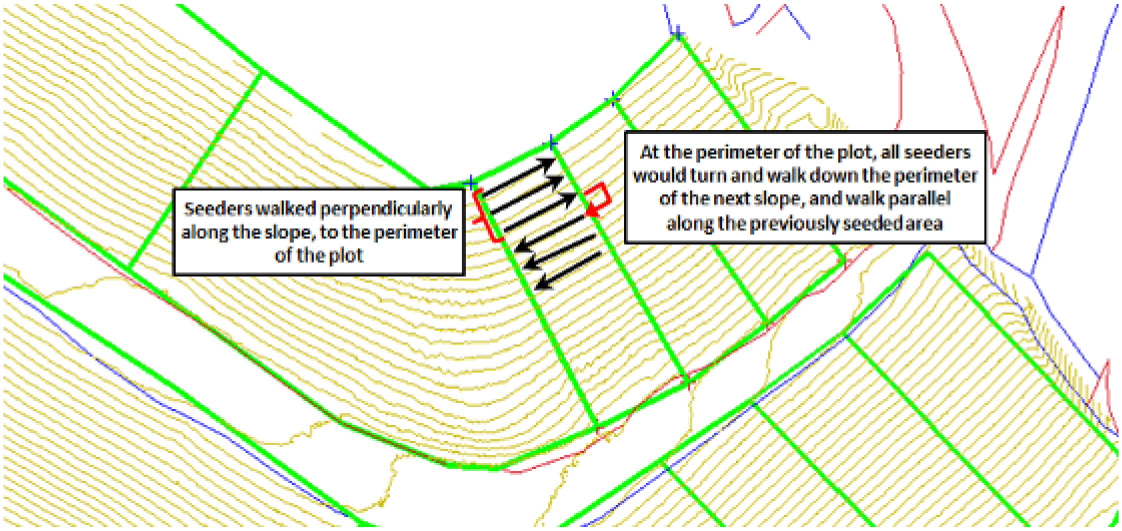

Figure 22 – Schematic of seeders walking perpendicularly within perimeter of amendment plot.

Figure 23 – Seeding

Seeding Success

Vegetation parameters under investigation for the 2012 reclamation research period are based on the Minto Mine Reclamation Research Program 2009 Activities (Access Consulting Ltd.) to allow comparison to previous results. Three aspects will be focused on:

- Approximate percentage of ground cover by all established species
- Order of dominance of seeded species
- List of volunteer species

Success of seeding will be determined by estimating vegetation percent cover. This parameter will be used to compare establishment among the different overburden and amendment plots, giving an indication of which overburden can best support vegetation and whether amendments aid, hinder, or have no effect on establishing vegetation. Order of dominance will be recorded to optimize the dry land seed mix in the future, if necessary. If the chosen seed supplier does not have a specific species on hand, other species could be substituted or omitted if they are not seen in the plots within 1 to 2 years. List of volunteer species will be recorded to identify plants that are present in the seedbed or recruiting from external sources. These species deserve consideration in future reclamation work as they are well suited to specific site conditions and are available in abundance around site.

Parameters will be measured to coincide with the mature phonological stages of the majority of species under investigation. Plots seeded in late June and early July (UWS, UES and LES Plots) will be focused on. These results will be included in the 2012 Annual Reclamation Research Report. Percent cover estimations may be gathered for all plots in mid-June 2013 to estimate re-establishment of these plots and seeding success of LWS Plots, that were seeded in late August 2012.

3.1.3 Erosion Control

In spring 2012, a considerable amount of overland flow was noted from the snow on the surface of the MWD melting and moving towards the steeply slopes overburden plots, as the upper surface of the MWD is gently graded towards those slopes. To capture and reduce erosion caused by this overland flow and from precipitation events, a ditch was constructed into the waste rock surface of the MWD (see Figure 24). The position of the ditch was chosen by previous observations of water movement and field fitting using an inclinometer. It is approximately 5 m wide by 1.5 m deep, with excavated material placed on the south side of the ditch to create a berm (see Figure 25).

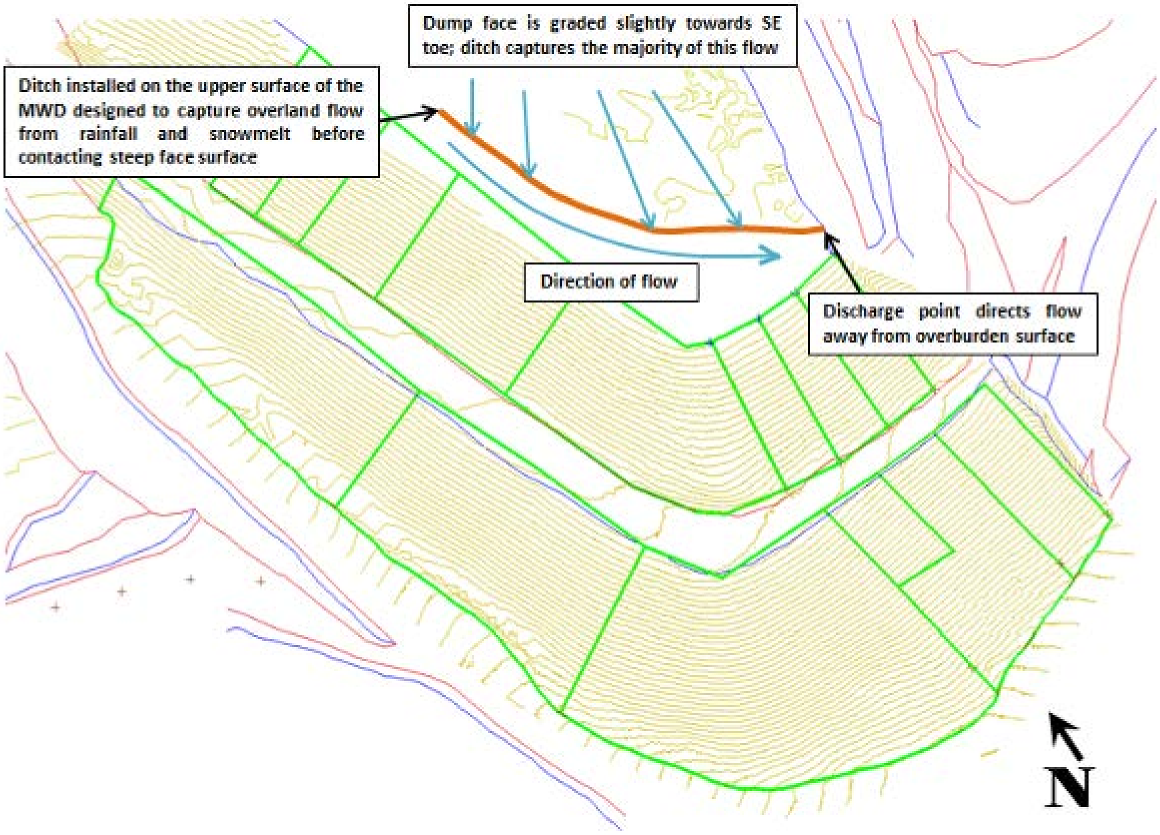

Figure 24 – Location and function of MWD ditch

Figure 25 – Construction of ditch on MWD's surface. Note berm along south side

3.2 Growth Media

The natural vegetation found on undisturbed sites around the mine generally provides information of the underlying soil properties, including texture, drainage, and pH, and the level of available nutrients that presently occur at the site. A soil sampling program was initially conducted in the project area during 1994 as described in the original environmental assessment report. The results of this program provide the basic information required for reclamation planning. Additional soil sampling on disturbed sites will be completed as part of ongoing reclamation research in order to determine areas of localized nutrient deficiencies.

Plants require, as a minimum, a medium that will allow roots to penetrate, that will retain adequate moisture and that contains suitable levels of nutrients for successful growth. Diamond drilling completed in the 1970's indicated that the Area 1 pit was covered by as much as 60 m of overburden. Ice rich materials are present to the south in an area where permafrost depths are estimated to be 18 m based on borehole logs in the area. The overburden from Area 1 generally consists of silt and fine sand with varying amounts of organic material and occasional layers of peat and gravel. The thickness of overburden required to retain water will be confirmed by trial, as the depth of growth media placed will be varied and soil moisture measurements compared with revegetation success on the various plots will suggest an optimum depth of overburden placement for revegetation measures.

3.3 Engineered Covers

Engineered cover systems are proposed in order to reduce metal loadings to the receiving environment. The scope of work that has been developed for ongoing research into cover design has been developed to ensure that an appropriate closure strategy for the waste rock and tailings areas can be developed. Minto will work with SRK Consulting (SRK) on this reclamation research element.

Specific tasks associated with the ongoing research include:

- Inventory of Cover Materials

  The DRP stipulates approximately 550,000 m^3 of cover material be available, all of which will be stored in the Reclamation Overburden Dump (ROD) which is currently under construction. Overburden investigations suggest a fair degree of variability in these materials and some consideration has been given to possibly segregating materials within the ROD to allow more flexibility in cover design. The segregation of the materials could be beneficial for the creation of layered covers, with the benefit that the nature of the different layers in concert could create significant infiltration limiting effects that a single layer cover may not be able to achieve. SRK Consulting (SRK) has been contracted to assist in developing a more comprehensive understanding of the current and future inventory of cover materials. Based on SRK's preliminary screening of available data it would appear that variations in the materials are not significantly different to conclusively identify performance differentiators such as infiltration limiting layers, store-and-release material or capillary break material, and therefore segregation may not be beneficial. Part of the work with SRK proposes to work with Minto to evaluate this in greater detail.

The work scope will also reconsider the site wide materials inventory of candidate cover materials, as it is not clear whether there are materials that are suitable for use as barrier or capillary break layers. It is critically important to verify the overburden materials inventory as the design of a cost effective cover is greatly affected by the availability of local materials.

- Characterization of Cover Material

  To date there has been a reasonable degree of physical characterization of the overburden soils, and some further characterization is ongoing as pre-stripping is being executed. No hydraulic property testing was, however, been completed prior to 2012 and such testing was identified as critically important to allow proper assessment as to the suitability and likely performance of these materials as cover layers.

  Minto developed a sampling and testing program with recommendations from SRK to properly characterize the overburden properties. Some soil characterization sampling was conducted in the summer of 2012 and sample analysis results will be presented in the Reclamation Research Program Annual Report.

- Scoping Level Cover Assessment

  Using the findings of the previous tasks, coupled with a more thorough review of all relevant available data, SRK will prepare a scoping level cover assessment for the Minto site. This assessment will evaluate specifically what type of covers could be constructed at the site using the locally available materials and how those covers can be expected to perform against the closure objectives set for the site. This assessment will rely heavily on SRK's experience with cover systems in similar climates. A basic ranking system will be used to allow evaluation of the different cover variants against parameters such as functionality, longevity, cost, uncertainty, etc. This will provide the framework to establish the appropriate trade-off studies to undertake as well as help define whether cover trials may be needed and, if so, what properties should be evaluated.

- Trade-off Analysis

  Covers are one of many possible remediation strategies that can be adopted to meet site wide closure objectives. Examples of other strategies include water treatment and waste relocation. The scoping level cover assessment completed in the previous tasks will identify a likely range of costs for application of covers at Minto. Appropriate trade-off studies will therefore be undertaken as part of this task to determine if there are more cost-efficient closure strategies available worthy of further consideration. An example of a trade-off study may be constructing a rudimentary isolation cover coupled with a passive water treatment system vs. construction of a high quality infiltration reducing cover. The outcome of this task would be justification to focus planning and/or research initiatives towards specific remediation strategies, which may or may not include covers.

- Maximize Benefit from Progressive Reclamation of MWD

  Construction of the aesthetic cover on the MWD lower face in 2012 offers an ideal opportunity to gather data that would be very beneficial towards improving an understanding of how the site specific soils would perform as cover material.

  As part of this task SRK will work with Minto to recommend a testing and monitoring program that intends to fulfill these needs. This includes tests related to constructability, material characterization (in-situ and laboratory), as well as short and long term performance criteria, including erodability which may be a very important consideration in this climatic regime.

- Develop Appropriate Cover Trial Program

  Based on the outcome of many of the preceding tasks SRK and Minto will, design a fit-for-purpose cover field trial program should it be determined to be beneficial. It is premature to suggest what this program may look like as it will be designed to specifically address uncertainties that have been demonstrated to exist as part of the work described under the preceding tasks.

3.4 In-Pit Water Treatment

It is recognized that when mining has been completed or after tailings deposition in the pits has reached its final depth, open pits will have the potential to provide tangible benefits for managing and improving site wide water quality and flow rates. The open-pits can serve a variety of functions ranging from providing settling time to enhance removal of sediment and TSS, to moderating storm flow hydrographs, to reduction of metal and organic contaminant loads through both microbial and physical processes.

Studies to date have focused on preliminary water quality assessment and limnocoral studies. Additional options for in-pit water treatment will be evaluated in connection with the mine closure alternative assessment and multiple accounts analysis. The section below provides details and findings on preliminary limnocoral studies conducted in the open pit.

3.4.1 Limnocorral Studies

Four test limnocorrals were installed in the Area 1 Pit to test in-pit microbial treatment of nitrate and selenium (as selenite/selenite), and to evaluate the effects of these treatment processes on other metals in the water column. The limnocorrals were initiated in October 2012, and will be continued through the winter and into the spring, making adjustments as necessary based on analytical results and as the mine pit is affected by tailings deposition.

The treatment method for the removal of these constituents is biological reduction, where nitrate is reduced to nitrogen (gas), selenium (as selenite/selenite) is reduced to elemental selenium (solid). In the higher doses of electron donors, sulfate reduction is also expected; in this case, some metals may be removed as sulphide precipitates.

The limnocorral study is part of an ongoing program to evaluate the feasibility of passive treatment at the Minto Mine site, and the results of this study will be used to design possible larger scale trials in the lake and/or will inform other potential passive treatment studies at the site.

Test Setup: Limnocorrals were filled with pit water and a baseline sample was collected to measure baseline chemistry. Field parameters and constituents required to be measured for discharge under the water licence have been measured to provide a baseline along with microbial abundance measurements were measured at the initiation of the test. The dimensions of the limnocorrals are approximately 3 meters in diameter by 10 meters deep with a total volume of approximately 70 m^3. Sediment from a natural wetland area at the edge of the water storage pond was added once the limnocorrals were filled to provide a natural microbial inoculum source, and carbon sources were added to the water column through a recirculation pump.

Test variables: The primary test variable evaluated in this program is the concentration of dissolved organic carbon on reductive reactions. The liquid source of organic carbon is a sugar syrup (molasses), and an alcohol (ethanol). The secondary variable evaluated is the addition of a solid phase organic carbon and surface attachment source (wood chips), on the development of reducing conditions and treatment effectiveness. The volume of wood chips added was 15 cm depth or approximately 1 m^3 per limnocorral. Sediment from the edge of the water storage pond was used as a microbial inoculum, as the preliminary work done in 2008 showed denitrification and selenite reduction effects was achieved by adding a carbon source to this pond, indicating microbes capable of these reactions are present in the water storage pond.

Test Limnocorral	Inoculum (site sediment)	Molasses/Alcohol	Wood Chips
Control	Yes	No	No
Low carbon with surface area	Yes	40 mg/L each	Yes
High carbon	Yes	120 mg/L each	no
High carbon with surface area	Yes	120 mg/L each	yes

Analytical: Field parameters and constituents required to be measured for discharge under the water licence were measured at baseline and monthly during November; and then when ice thickness is sufficient, twice under ice during winter, proposed to be late January and March. Depending on observations of field parameters and analytical results, the test may be extended beyond this time.

Field Parameters: Field measurements that are beneficial to interpretation of the test include pH, dissolved oxygen, redox potential (mv), and conductivity (µS/cm). The frequency of these measurements will coincide with water the sampling outlined above and will be conducted within the water column to evaluate variability within the water column and any trends of stratification.

Licence Parameters: Constituents required to be measured under QZ96-006 are:

- pH
- Ammonia - N (total)
- Nitrite - N
- Nitrate - N
- Total Suspended Solids
- Aluminum (total)

- Cadmium (total)
- Chromium (total)
- Copper (total)
- Iron (total)
- Lead (total)
- Molybdenum (total)
- Nickel (total)
- Selenium (total)
- Zinc (total)

Microbial Parameters: Total aerobic bacteria and sulphate reducing bacteria are all relevant microbial tests that will be measured during the first 3 months; the need to continue will be evaluated after the 3rd month results are achieved.

The results of these studies will provide valuable insight into the potential for incorporating in-pit treatment into the overall operational water treatment and reclamation strategy. It is anticipated that further testing will be required to enable detailed design.

3.5 Passive Treatment of Surface Waters and Shallow Groundwater

Consideration will be given to a wide variety of passive and semi-passive treatment options. The process for identifying and evaluating passive treatment options is discussed in Section 2 and will be completed in connection with updating of the RCP.

The range of potential passive treatment technologies to be considered includes, but is not limited to: constructed treatment wetlands, biochemical reactors, permeable reactive barriers, microbial mats, in-situ biological treatment and aeration.

Testing of passive and semi-passive water treatment approaches at Minto will have the following objectives and methods:

1. Validation of mass loading reduction by passive systems:

   Test cells of wetlands with anaerobic zones and wetland plant zones are proposed in order to determine the potential removal rate of metals as a function of surface area and retention time. The treatment test cells would be constructed to receive water pumped from the current treatment plant influent feed and pretreat this water prior to being allowed to flow under gravity back into the pre-treatment storage pond.

   The treatment cell would contain a vegetation zone with wetland species that are common to the Minto area. This would be an upflow cell approximately 1 meter thick with year-round flow. Overflow from this cell would be routed into test cells with mixtures of locally available coarse media (clean gravel) and organic media such as wood chips or peat. These cells would test the anaerobic removal rates as a function of retention time within the media, as confirmed by tracer injection.

2. Evaluation of pit lake pretreatment:

After the results of the limnocorrals have been analyzed, a follow-up test that evaluates the dynamics associated with utilizing the pit lakes as water management and treatment features will be set up. A deep lined trench or similar open water structure would be filled with mine water and inoculated by sediment from local bogs or wetlands. A carbon source would be added to the pit and annual water exchanges will be allowed in the spring time to mimic freshet inflows. Water would be allowed to exit through a gravel bank (with possible mixed wood chips) which would allow filtration as well as development of sulphate reducing bacterial activity on the surface of the gravel, similar to a biological reactor. Monitoring would be performed to evaluate open water removal rates and removal rates through the gravel bank.

Outflow from these biologically active systems may require aeration which can be done in a passive manner by allowing the overflow from the test cell to flow through falls and riffles to cause the materials to aerate, with settling rock pool to provide residence time. It is anticipated that aeration will be critical in optimizing passive treatment in the following manner:

- Aeration of surface waters encourages an active aerobic microbial community, which can aid in removal of dissolved iron and manganese from either the anaerobic treatment settings or in pore waters from waste stacks (tailings or waste rock).
- Aeration of surface waters will directly support iron oxidation and precipitation, which then leads to trace metals removal by co-precipitation or sorption on the precipitated iron oxides.
- During the initial phases of reclamation, as covers are taking effect, initial wetlands filling and plant growth is occurring, or pit lakes are setting up a stable limnological cycle, there will be the potential for seasonal excess organics leaching either from soils or present as algae blooms in the surface water.

In full scale application, it is anticipated that the aeration features will be installed in the flowpath from the passive treatment areas and covered mine waste areas. These downgradient aeration systems will be useful to aid in the protection of surface waters from excess biological oxygen demand (BOD) which can leach from newly saturated materials (in pits or wetlands) or from organic-rich cover materials. Without this, excess BOD may otherwise reach the surface waters and cause depletion of oxygen resulting in deleterious effects to fish. The aeration polishing will reduce the BOD such that surface waters will be protected during these transitional phases of the reclamation.

4 Summary

Results of the programs and studies outlined in this document will be summarized in Reclamation Research Annual Reports. Minto will continue with an active reclamation research program as the Reclamation and Closure Plan is continuously refined and updated. The objective of reclamation research is to ensure and achieve an effective closure plan and ultimate successful closure of Minto Mine at the end of production.